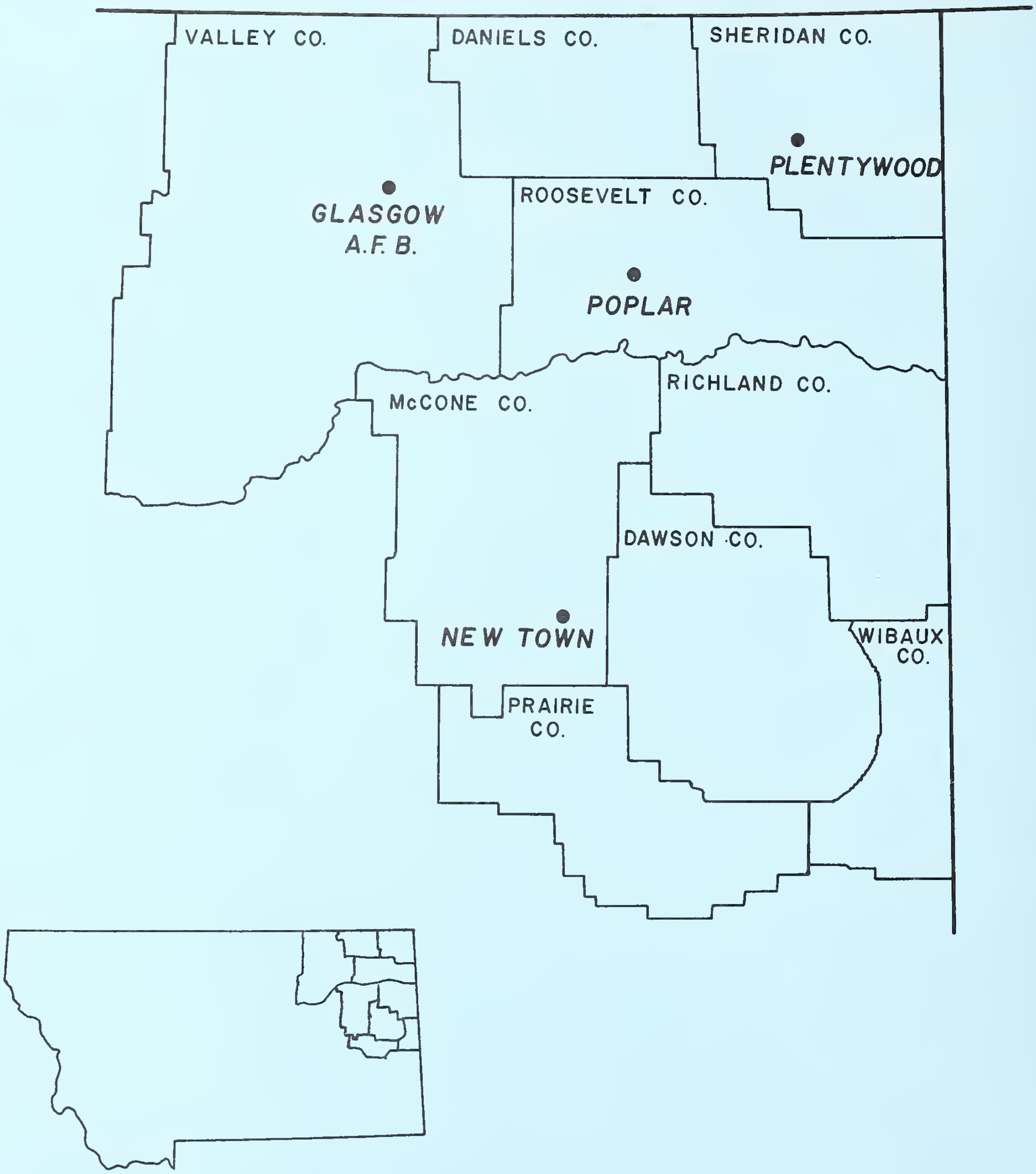
COAL GASIFICATION

Volume I

MONTANA ENERGY and MHD RESEARCH and DEVELOPMENT INSTITUTE, INC., Butte, Montana



POTENTIAL COAL GASIFICATION SITES IN
NORTHEASTERN MONTANA

MONTANA

NATURAL GAS

DEMAND STUDY

FINAL REPORT

prepared for

STATE OF MONTANA AND U.S. FEDERAL ENERGY ADMINISTRATION
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prepared by

Environmental Engineering Division
MONTANA ENERGY AND MHD RESEARCH AND DEVELOPMENT INSTITUTE
Butte, Montana

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STATEMENT

This report was prepared by professional consultants at the Montana Energy and MHD Research and Development Institute under contract with the Office of the Governor, State of Montana, with funds provided by a state federal cooperation agreement with the U.S. Federal Energy Administration (FEA). Neither the Office of the Governor nor FEA has approved the report, nor do they guarantee the accuracy or the completeness of the data. The statements, findings, conclusions, and recommendations contained in the report are soley those of the contractors and do not necessarily reflect the views of the Governor of Montana or FEA. This report is the result of tax-supported research and, as such, is not copyrightable. It may be reprinted freely with the customary crediting of source.

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EXECUTIVE SUMMARY

December 1976

Energy is a vital component in almost every aspect of modern man's life. Energy use has increased dramatically as populations have grown and lifestyles have changed to include energy consuming aspects such as: large climate-controlled living spaces, a high degree of mobility, varied and super abundant diets, and a supply of convenient or pleasing goods and services. We have become heavily dependent upon the concentrated and readily usable forms of stored energy. Recent experiences have greatly changed the general outlook on energy. Embargoes, escalating costs, and alarmed forecasts of permanent, deepening scarcity have created widespread concern among officials, experts, and the general public. It now appears that serious energy shortages are definitely probable or even inevitable. Suddenly it has become very important to learn as much as possible about future energy conditions. At least we would like to know the magnitude of the problem that is developing. Hopefully, advanced knowledge will make it possible to choose policies that avoid or mitigate energy crisis conditions, such as the one projected to begin in 1985 in Montana.

As in many other regions of the country, the supply of natural gas in Montana may not be sufficient to meet future needs. One method to avoid this problem in Montana may be to produce SNG (synthetic natural gas) using the state's extensive coal reserves. The purpose of this study is to determine if SNG production may serve Montana's future natural gas demands and prevent an energy crisis from developing.

Determining the demand for SNG is essentially a balancing problem. The SNG demand is the additional production required to balance natural gas requirements with the supplies available. Thus, the demand for natural gas must be determined before the demand for SNG can be found. Natural gas cannot be considered alone as it competes with other fuels. The forecasted demand for natural gas (including SNG) in Montana

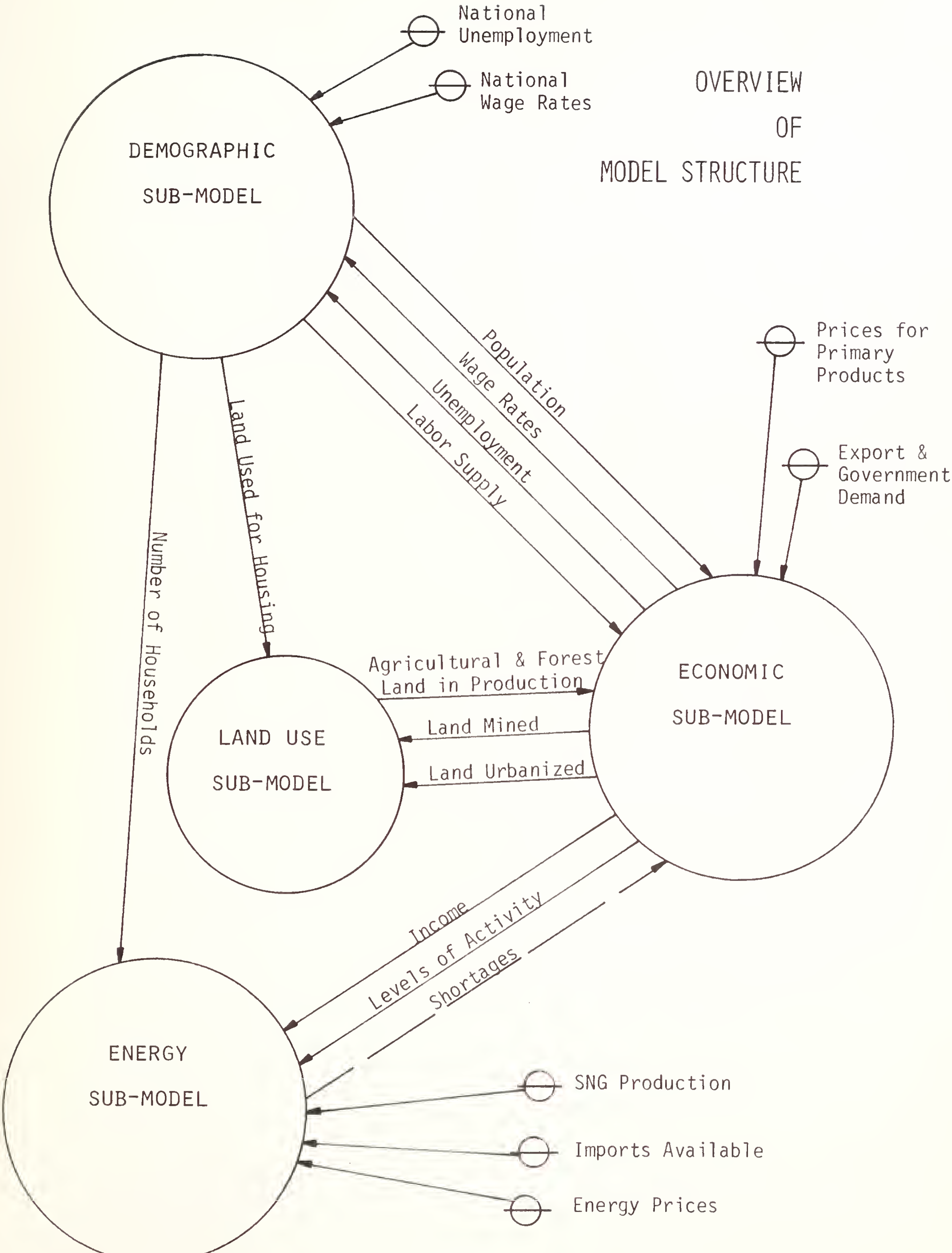
to 2000 AD has been determined by the level of activity in the Montana economy. A dynamic systems simulation approach was selected as most appropriate for the model. This approach takes into account the various interrelationships and feedback effects found in the Montana economy. The model is composed of several sub-models, each dealing with a certain area of the economy. Overall structure for this model is illustrated in Figure 1. The model is similar in concept to the Oregon State Simulation Model, and the structure of some of the sub-models basically is the same as their Oregon counterparts. The Montana Futures Project input/output model of the Montana Department of Community Affairs also was used in the formulation of the model.

Baseline Gas Demand in Montana

A baseline gas demand in Montana was established for the period between now and the year 2000 (see Figure 2). This baseline case represents a continuation of current policies and practices; in other words, business as usual. In this case, the demand for natural gas is not considered to be supply or price limited. Significant overall economic growth is forecasted in Montana, but not all sectors of the economy will experience the growth. The petroleum industry and metal mining and processing are expected to provide a smaller proportion of economic activity in the year 2000 than now. This decline is due to a shrinking resource base and steadily increasing costs of extraction. Forestry and kindred industries are expected to grow modestly but steadily through the end of this century. Agriculture will remain the dominant industry of Montana throughout the remainder of this century and shows significant economic growth. The coal industry should grow dramatically and will be the second largest industry in Montana by the year 2000. The natural gas demand for the baseline case would be 83 billion cubic feet in 1980 and approximately the same in 1985. Demand would be about 89 billion cubic feet in the year 2000, with peak demand in the mid-90's of around 94 billion cubic feet per year.

Residential Conservation Effects

Since the greatest volume use of residential gas is in home heating, the focus for this case was concentrated in this area. Reduced energy use per household is due to increased insulation, improved weather-stripping, and the use of storm windows and doors. Additional savings are realized from altered living habits. Home energy conservation primarily is a function of gas price. The gas price is assumed to rise from current levels to $4.50/MCF in the year 2000. Gas demand approximates 80 billion cubic feet in 1980 and declines to 77 billion cubic feet in 1985. Demand for natural gas will be about 74 billion cubic feet in the year 2000, with a peak in the mid-1990's of approximately 85 billion cubic feet per year.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Imports Available
Energy Prices

Figure 1

Industrial Energy Substitution

Industrial fuel switches were divided into two types. First, industrial fuel substitutions considered firm are those that currently are underway or are scheduled for completion by 1980. These switches in fuel usage are caused by various factors such as environmental concern, fuel supply uncertainties, and relative fuel costs. Next, the industrial fuel substitution was extrapolated beyond 1980. The extrapolated fuel substitution is a function of relative fuel costs and the payback period for conversion. The combined substitutions project a gas demand of 69 billion cubic feet in 1980. Demand falls off to 61 billion cubic feet in 1985 and is about 62 billion cubic feet by the end of this century. Peak usage in the mid-1990's is approximately 67 billion cubic feet. The price of gas is assumed to rise from today's prices to $4.00/MCF by the year 2000.

Gas Price Effects

Three price scenarios were selected as representative of low, medium, and high gas prices. Prices are for residential gas use; industrial gas prices were assumed to be lower by $.50/MCF. Demand in the residential and commercial sector is forecasted to increase toward a peak of 41 BCF/yr in 1990 and then drop to 35 BCF/yr in 2000. Industrial demand for natural gas is highly price sensitive. Consequently, demand in the "industrial and other sectors" is forecasted to decline from 38 BCF/yr in 1975 to approximately 18 BCF/yr in 2000 as a result of gas price increases from $2.00/MCF in 1977 to $4.00/MCF in 2000. These projections indicate that by 1985, this residential and commercial demand for natural gas will represent almost 60% of the total demand. By 1990, the industrial sector demand for natural gas is expected to drop to about 28% of the total.

Conclusions

Natural gas demand in Montana (including demand for SNG) will decline from the present level of about 80 billion cubic feet per year to 50-70 billion cubic feet per year by the year 2000. The decline in gas demand after 1980 is caused primarily by projected increases in the gas price to consumers. Even for modest increases in price (to $3.00/MCF in the year 2000), the demand is reduced by about 30% from current demand. A price of $3.00/MCF by the year 2000 is an average price growth rate of 2.5% per year. An average price growth of 5.75% (to $6.50/MCF in 2000) will drive gas demand down to about 60% of current levels by the year 2000.

The minimum available natural gas supply situation in Montana, as projected by the recent staff report of the Montana

Environmental Quality Council,* indicates a substantial energy and economic crisis could occur in Montana about 1985. This projected crisis would result from an unsatisfied energy demand previously satisfied by natural gas. One way to mitigate and possibly avoid this projected crisis would be to provide for SNG production in Montana beginning about 1985. In Figure 2 is shown the projected Montana SNG demand beginning in 1985. This forecasted demand calls for the production of 28 BCF/yr of SNG starting in 1985 with an additional 28 BCF/yr of SNG coming on line in 1992.

If this projected natural gas demand is not satisfied by natural gas/SNG production, its energy equivalent would have to be satisfied by alternate energy sources, such as electricity, coal, wood, etc. Renewable energy resources are not expected to be significant in this time frame. If this projected energy demand is not satisfied an economic crisis and social disruption in Montana should be expected.

SNG production in Montana, starting in 1985, could be a means to prevent an economic and social crisis as well as a way to "buy time" needed to develop and provide alternate, renewable energy sources for the residential, commercial and industrial sectors of Montana's economy beyond 1985.

* "Montana Natural Gas Supply Crisis," by Thomas W. Frizzell, Montana Legislature, Environmental Quality Council, Helena, Montana, December 1976.

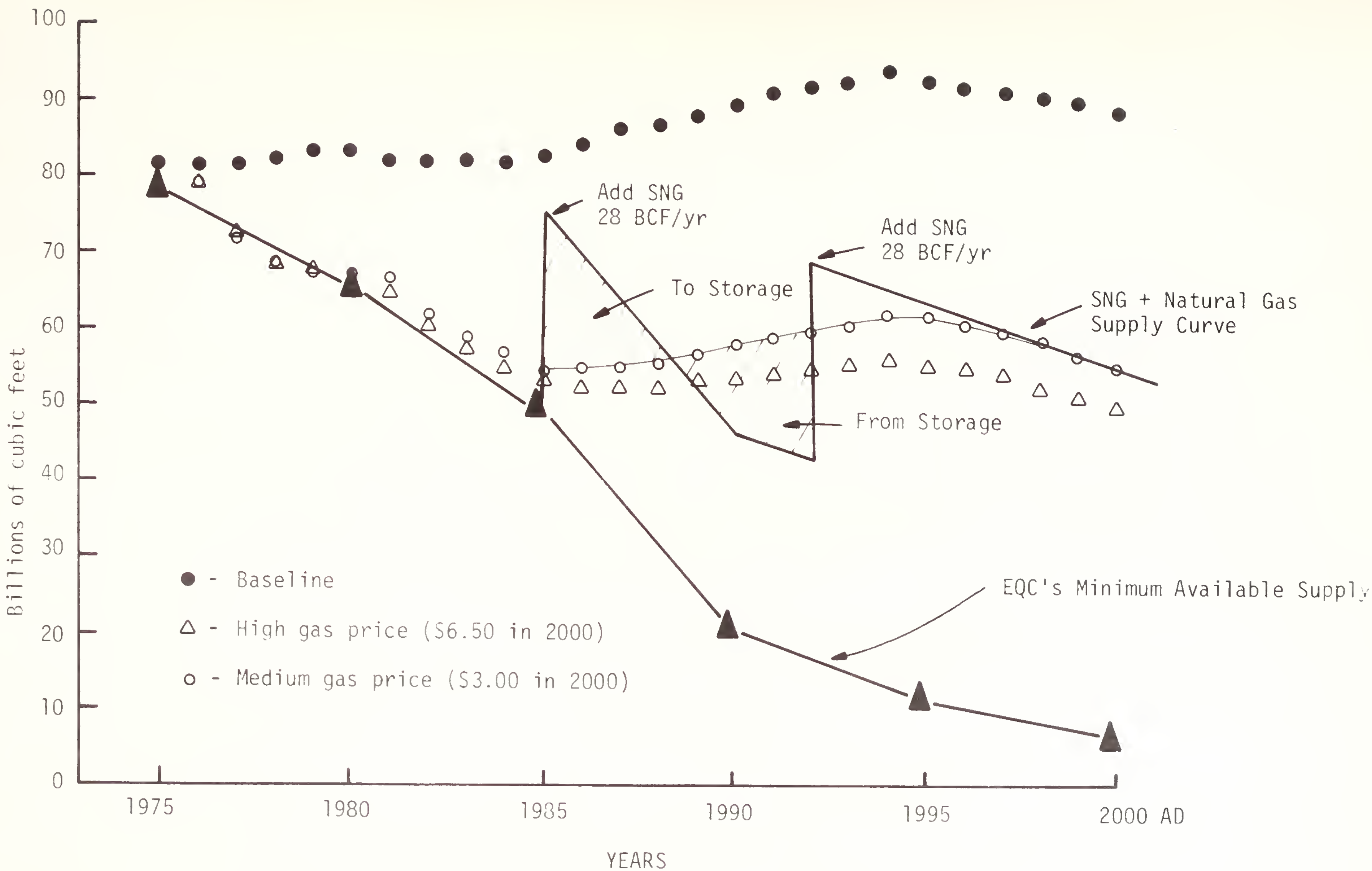

Figure 2.--Montana Substitute Natural Gas Demand

I. INTRODUCTION

As in many other regions of the country, the supply of natural gas in Montana may not be sufficient to meet future needs. One method to avoid this problem in Montana is to produce SNG (synthetic natural gas) using the state's extensive coal reserves. The purpose of this study is to determine the demand for SNG in Montana through 2000 A.D.

Determining the demand for SNG essentially is a balancing problem. The SNG demand is the additional production required to balance natural gas requirements with the supplies available. Thus, the demand for and supply of natural gas must be determined before the demand for SNG can be found. Natural gas cannot be considered alone as it competes with other fuels. Major conversion of industry gas uses to coal and electricity certainly are possible and can affect the demand for natural gas significantly. The cost of producing SNG is likely to be different from the natural gas obtained from conventional sources. Thus, SNG may enter the market place and compete at different price levels than other natural gas.

The approach used here was to develop a model of Montana's economy on which energy demands can be based. The complete documentation of the model is contained in appendices A-D of this report. The industrial and commercial demands for energy are based upon the levels of activity in the corresponding sectors of the economy while residential demands are based upon the number of households and their income. In addition, the effects of inter-fuel competition and conservation are considered.

The primary modeling technique used is dynamic systems simulation. This methodology deals with the forces causing change in the economy and should be well suited for the transients which are likely in Montana's future. It also allows the model to be based more closely on the actual processes and actions which occur in Montana's economy. The dynamic simulation is combined with input/output analysis in determining levels of economic activity. The use of the input/output analysis assists in obtaining more detail in this critical area.

Once developed, the model was used to analyze the effects of inter-fuel substitution and various energy conservation scenarios. Some industries in Montana recently switched from gas to other fuels, and more substitutions are projected for the future. Residential heating is a major gas use in Montana; conservation in that area was modeled for several projected gas price levels. Fuel substitution and energy conservation will be significant factors in the gas demand picture for Montana.

II. DYNAMIC SYSTEM SIMULATION MODEL OF MONTANA'S ECONOMY

The demand for natural gas (including SNG) in Montana is determined by the level of activity in the Montana economy. The SNG study group felt that it would be worthwhile to develop a computer model of the economy to aid in demand analysis. A dynamic systems simulation approach[1] was selected as most appropriate for the model. This approach takes into account the various interrelationships and feedback effects in the economy.

The model is composed of several sub-models each dealing with a certain area of the economy. Overall structure for this model is illustrated in Figure 1. The model is similar in concept to the Oregon State Simulation Model,[2] and the structure of some of the sub-models basically is the same as their Oregon counterparts. The Montana Futures Project[3] input/output model also was used in the formulation of the model. Each sub-model is discussed separately in the following sections.

A. Demographic Sub-Model

The demographic sub-model predicts both the number of people that will be in Montana and the number of households in the state. Projections are based upon current population and predicted net migration. Migration is affected by the difference between Montana unemployment levels and national unemployment levels.

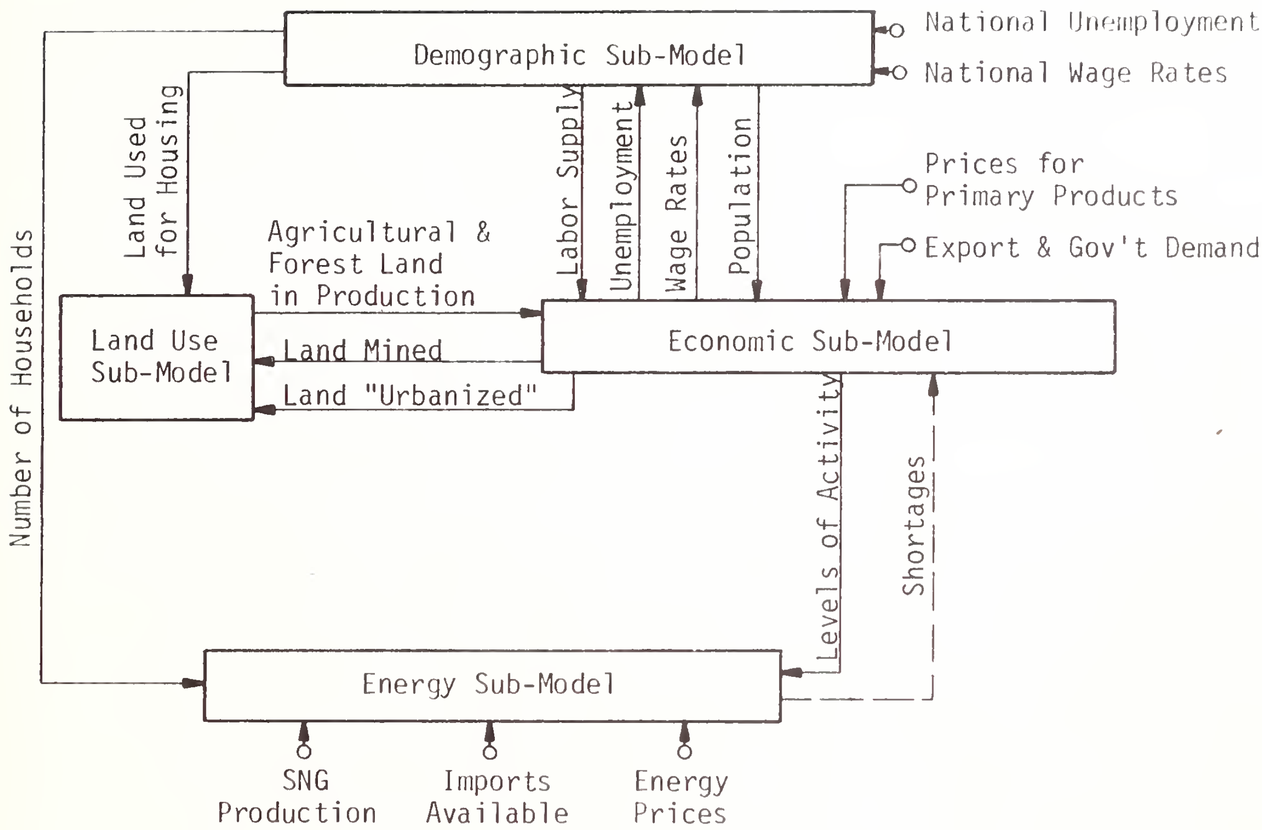

Figure 1.--Overview of Model Structure

B. <u>Land Use Sub-Model</u>

The land-use component maintains a current inventory of land in each of six categories. Residential land demand is a function of the rate of new household formation and the residential conversion density (which originates in the demographic component). Demand for commercial/industrial land is determined by the rate of employment and the employees/acre. This is generated by activity levels in the industrial sectors of the economic component. The figure for total land converted from agricultural to urban land is obtained from the sum of the demand for residential and commercial/industrial land.

Mining land is converted from agricultural land by a scenario variable derived from standard coal production per year. Waste land is derived by taking the product of the land mined and the fraction of revegetation (this fraction being a technical policy input).

Forest land accounts for all the land upon which commercially harvestable timber is growing. Agricultural land can be converted to forest land; however, this is unlikely in Montana. Forest land may be converted to wilderness land and vice versa by policy input.

C. Economic Sub-Model

Five separate models are used for the primary economic activities: agriculture, forestry, coal mining, oil and gas production, and non-energy mining. Since the output of the petroleum refining and primary metal processes depends mainly on the amount of Montana oil produced plus crude oil imports and metal mined, they also are considered separately. This part of the model can be considered supply limited. The output of these sectors plus consumer expenditures, export demands, government spending, and capital expenditures, drive an input/output model for the rest of the economy. These activities can be considered demand limited. The outputs then are used to determine total employment and income.

Each of the models for the primary activities and for petroleum refining and primary metal processing will be discussed separately. The capital investment and employment

models also are discussed separately.

D. Agricultural Sub-Model

The agricultural sub-component of the economic model is divided into two parts, agricultural production and capital formation.

Agricultural Production: The amount of agricultural land and the level of capital employed are combined (utilizing a modified Cobb-Douglas production function)[2] to generate the production level. The gross agricultural production is converted to net farm receipts by subtracting the aggregate expenses incurred in production. The production expenses fall into four categories: direct operating expenses, labor expense, interest expense, and property tax expense.

Capital Formation: The agricultural capital formation model starts with the value of net farm receipts developed in agricultural production and determines the resulting change in capital. If net farm receipts are greater than zero, a portion is used to purchase new capital. Depreciation of capital stock is assumed to occur at a rate that is proportional to the installed level.

In the event that net farm receipts are less than zero, liquidation can occur. If the magnitude of the loss exceeds a specific fraction of gross production, it is assumed that the agricultural community will be forced to further reduce the level of owned capital stock by liquidating it at its

salvage value; otherwise, capital is simply allowed to depreciate without replacement.

E. Logging Sub-Model

The principal assumption in the logging sub-model is that the logging sector of Montana's economy in the long run is driven by the projected inventory of standing mature sawtimber available to be cut in each year. The total capital to harvest the allowed timber cut is adjusted by technology and the future capital required. Additional capital is a relationship between the total capital required and the present level of capital.

The annual cutting rate is determined by calculating the difference between the standing timber available to cut and the maximum possible cut given the current level of installed capital.

F. Coal Mining/Non-Energy Mining Sub-Model

The models for coal mining and non-energy mining are identical in structure. Only the parameters are different. For the sake of simplicity, they will be discussed together here.

The productivity and cost for mining are determined by relating mining cost and capital cost functions to the total quantity that has been mined. A cost distribution function determines what fraction of total possible output is economical. This is used to determine the actual output. Profit rate and the rate of return are calculated by subtracting

mining expenses from mining income.

G. Oil and Gas Sub-Model

The oil and gas model consists of parallel, coupled models--one for oil discovery and production and one for gas discovery and production. The models are coupled since oil production normally has some gas production associated with it and production from gas fields usually results in the production of some liquids as well. Similarly, when exploration for oil fields is carried out, there is some probability of finding a gas field (or vice versa). The following discussion deals only with oil exploration and production since the structure is the same for gas.

When oil is discovered, it is placed in the producing level and information is retained as to the age of each discovery. Four functions are required to describe the performance of producing reservoirs.

The production function traces a typical reservoir through the various stages of discovery, steady-state production, and finally, a long period of steady decline to depletion. The operating expense function shows the expenditures required to operate a producing field of a given age. The investment function gives the rate at which investment must be made in order to develop and maintain a field.

The variable cost of production is similar to the operating expense function except that it describes the cost

on the basis of unit of production for fields of each age. This function is used to compare the price to the variable cost.

The total oil production is the sum of the oil produced in oil fields plus the liquids produced in natural gas fields. The total income for oil production is then the oil produced in oil fields multiplied by the oil price--plus the gas produced in the oil fields multiplied by the wellhead gas price. The expenses for the production come from the total operating expenses plus the costs for capital. The net profit rate per barrel of oil is determined by subtracting the expenses from the income and dividing by the production rate.

The rest of the model deals with exploration. Two additional functions are required here. The depletion function gives the increase in drilling required for additional discoveries as more and more oil is discovered. The investment function gives the rate of investment in terms of the profit rate.

H. Petroleum Refining Sub-Model

Montana's petroleum refining is very closely related to the output of the petroleum sector. It also is dependent upon imports of crude oil. These factors are more important than actual demand for refinery products in Montana. Therefore, it must be considered separately rather than with the economic output model.

The vast majority of the refinery capacity in Montana is located around the Billings area. However, the pipeline system is such that the oil produced in the eastern part of the state is not available to these refineries.

In 1975 81% of the total oil refined in Montana was imported crude oil. However, it is difficult to predict the availability of crude oil imports in the future, especially Canadian imports. Thus, the refinery output will depend upon the available Montana production plus the available imports or the maximum output of current capacity.

I. Primary Metals Sub-Model

The output of the primary metals sector of the economy is dependent primarily upon the output of the metal mining sector. It also is very energy intensive. Primary metals output is assumed to be proportional to the non-energy mining output.

J. Economic Output Model

The economic output model is simply an input/output model for Montana. Outputs for agriculture, forestry, coal mining, oil and gas, non-energy mining, petroleum refining, and primary metals are all determined elsewhere. The direct input/output coefficients are used to determine the demands for other products due to these outputs. These demands then are treated as demands exogenous to the input/output model. Additional exogenous demands arise from consumer spending, exports, and government spending.

K. Capital Investment Sub-Model

The capital investment for the primary sectors is determined in their individual models. The same capital investment structure is used for all non-primary sectors.

The model uses exponential delays to average both the output and the rate of change for a sector. The averaged rate of change is added to the depreciation rate to get the total investment rate required. However, if this rate is negative, there is no investment. If it is positive, it is multiplied by the averaged output and the capital output ratio to determine the actual investment.

L. Employment Sub-Model

Employment is divided into three groups: agricultural, non-agricultural primary, and derivative employment. The primary reason this division is made is because wage rates for the different groups vary considerably. Levels of employment are determined from economic output and employee/output rates. Government employment should relate to government spending in much the same way that private employment relates to output.

The employment for the various sectors are summed to determine the total employment. The total work force available is determined by multiplying the total population by the employee/population projection. The total employment and the total work force are compared to determine the unemployment rate.

M. Energy Sub-Model

The energy sub-model is divided into a fairly detailed demand section and a simple supply section that obtains much of its information from the economic sub-model.

The demand for energy is analyzed along the traditional lines of residential, commercial, and industrial usage. Each part of the demand is treated somewhat differently and is discussed separately.

Residential Demand---The demand for residential energy is divided among its various end uses. These uses include the following factors:

Space Heating
Water Heating
Kitchen Ranges
Refrigeration
Clothes Drying
Air Conditioning
Other

The actual residential demand for a particular form of energy by a particular end use is determined by the following relationship:

$$E_{i,j} = A_{i,j} \times S_{i,j} \times TH$$

where

$E_{i,j}$ is the consumption of energy type i by end use j,

$A_{i,j}$ is the average consumption of energy for this type of end use in a typical household,

$S_{i,j}$ is the saturation of type j end use using energy type i, and

TH is the total number of households.

Industrial Demand---Industrial energy demand is determined separately for each sector. The use of a particular type of energy in a given sector is determined by the following relationship:

$$E_{i,j} - A_{i,j} * O_j$$

where

$E_{i,j}$ is the use of energy type i in sector j,

$A_{i,j}$ is the energy type i consumption per unit of output, and

O_j is the output of sector j.

Commercial Demand---There appears to be very little data available which gives details on commercial energy demand. This is a common problem for all energy studies. Usually everything that is left over is lumped into the commercial category.

The output for the commercial sector also was treated as a residual. It consists of all trade, service, and government sectors; the construction sector; and the communications sector. Total output for these sectors was 1,924 million dollars in 1974. The Montana Business Quarterly reports that income in Montana increased approximately 5% from 1972 to 1974. It was assumed that commercial output increased similarly. An adjusted output of 2,021 million dollars then was calculated. This value for output was used to calculate the energy coefficients.

N. Energy Supply

The energy supply part of the model is relatively simple compared to the energy demand. Most of the actual supply modeling is done in the economic part of the model which gives the total production of gas, oil, and coal. However, most of the coal production is destined for export, and a significant part of the oil and gas production is not available for Montana use.

O. Energy Conservation in the Residential Sector

The amount of natural gas used in the residential sector could change considerably as prices increase. There may be reductions in energy consumption due to fuel shifts, investments in home heating and energy saving devices, or merely by an adjustment in living habits. These changes could affect the total demand for natural gas significantly.

Our study of residential energy conservation focused on home heating since it dominates natural gas consumption in this sector. The substitution of other fuels for natural gas was eliminated since other fuels are not likely to be cost competitive to the point of causing major fuel shifts in home heating even when price increases are considered. However, existing methods for reducing heating requirements through home insulation were found to be cost effective.

Energy savings and cost data can be used to determine the return for installing insulation for various price scenarios in terms of a payback period.

A simple conservation model simulates the installation of insulation and the impact it has on natural gas for heating a typical Montana home.

In addition to the reductions resulting from insulation, significant energy saving could result from modified living habits due to high natural gas prices.

III. SCENARIO PRESENTATION

A. Baseline Gas Demand in Montana

A baseline gas demand in Montana was established for the period between now and the year 2000 (see Figure 2). The baseline demand assumes very little home energy conservation. Industrial fuel substitution is assumed to be minimal also. This baseline represents a continuation of current policies and practices.

The demand for natural gas is not considered to be supply limited. Significant overall economic growth is anticipated in Montana, but not all sectors of the economy will experience the growth. The petroleum industry and metal mining and processing are expected to provide a smaller proportion of economic activity in the year 2000 than now. This decline is due to a shrinking resource base and steadily increasing costs of extraction.

Forestry and kindred industries are expected to grow modestly but steadily through the end of this century. Agriculture will remain the dominant industry throughout the remainder of this century and shows significant economic growth. The coal industry should grow dramatically and will be the second largest industry in Montana by the year 2000.

This mixed economic activity will change the proportion of fuel demand in Montana. One rather dramatic effect of this change in fuel usage is a much smaller increase in natural gas

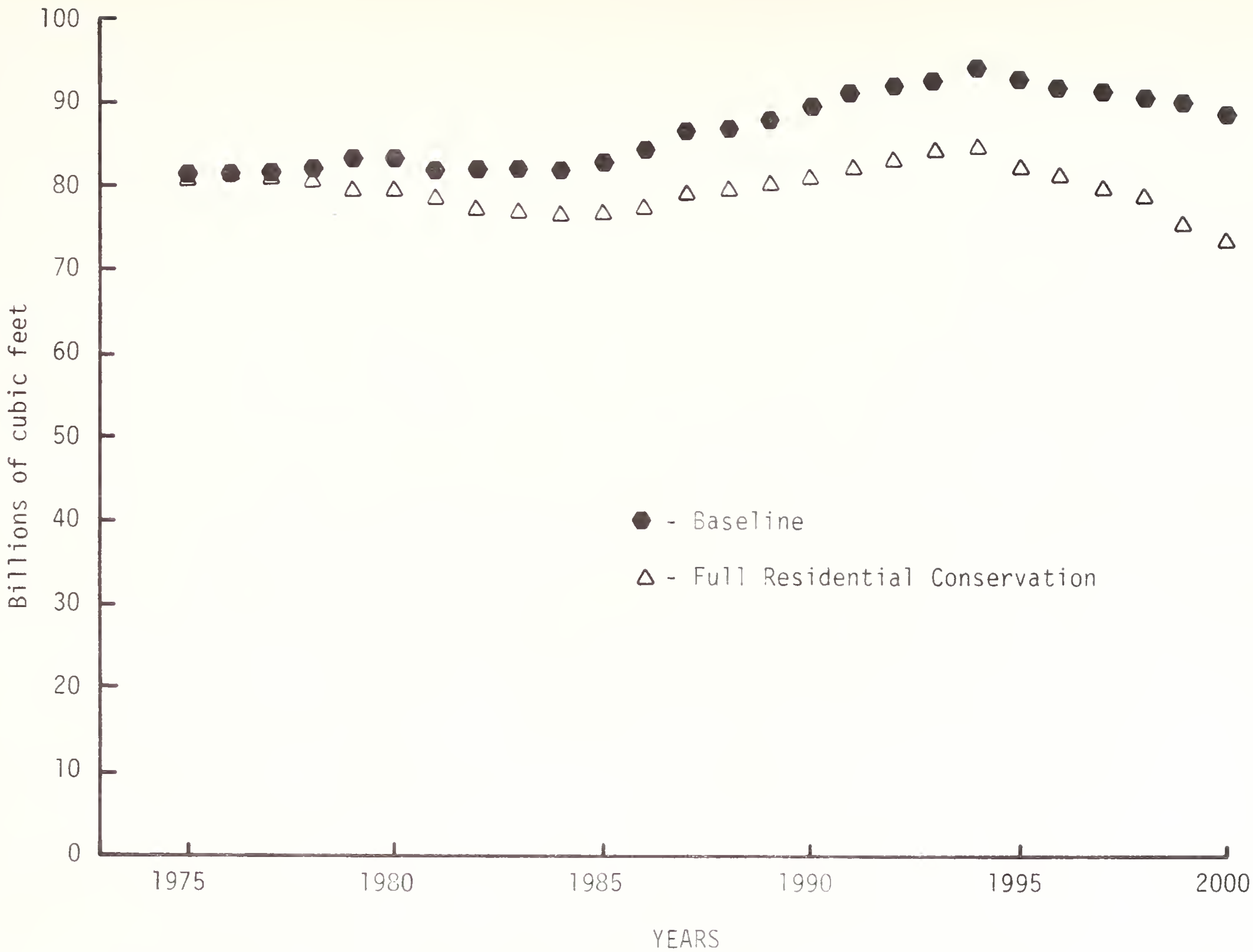

Figure 2.--Montana Natural Gas Demand

demand than has been experienced in the past. The demand for the baseline case would be 83 billion cubic feet in 1980 and approximately the same in 1985. Demand would be about 89 billion cubic feet in the year 2000, with peak demand in the mid-90's of around 94 billion cubic feet per year.

B. Residential Conservation Effects

The baseline case for gas demand assumes very little residential energy conservation. The first case to be considered after establishment of the baseline is the probable effect of significant home energy conservation. Since the greatest volume use of residential gas is in home heating, the focus was concentrated in this area. Reduced energy use per household is due to increased insulation, improved weather-stripping, and the use of storm windows and doors. Additional savings are realized from altered living habits. Home energy conservation primarily is a function of gas price.

Figure 2 shows the effect of home energy conservation on gas demand in Montana. The gas price is assumed to rise from current levels to $4.50/MCF in the year 2000. Gas demand approximates 80 billion cubic feet in 1980 and declines to 77 billion cubic feet by 1985. Demand for natural gas will be about 74 billion cubic feet in the year 2000, with a peak in the mid-1990's of approximately 85 billion cubic feet per year.

C. Industrial Energy Substitution

No industrial energy substitution is assumed in the baseline gas demand for Montana. The next step in the analysis is to see how substantial substitution of other fuels for gas affects gas demand. Fuel switches were divided into two types. Industrial fuel substitutions considered firm are those that currently are underway or are scheduled for completion by 1980. These switches in fuel usage are caused by various factors such as environmental concern, fuel supply uncertainties, and relative fuel costs. The industrial fuel substitution then was extrapolated beyond 1980. The extrapolated fuel substitution is a function of relative fuel costs and the payback period for conversion.

The effects of both types of industrial fuel substitution are shown in Figure 3. One curve shows the effects of firm substitutions only, while the lower curve represents demand when firm substitutions and extrapolated substitutions are combined. The combined substitutions project a gas demand of 69 billion cubic feet in 1980. Demand falls off to 61 billion cubic feet in 1985 and is about 62 billion cubic feet by the end of this century. Peak usage in the mid-1990's is approximately 67 billion cubic feet. The price of gas is assumed to rise from today's prices to $4.00/MCF by the year 2000.

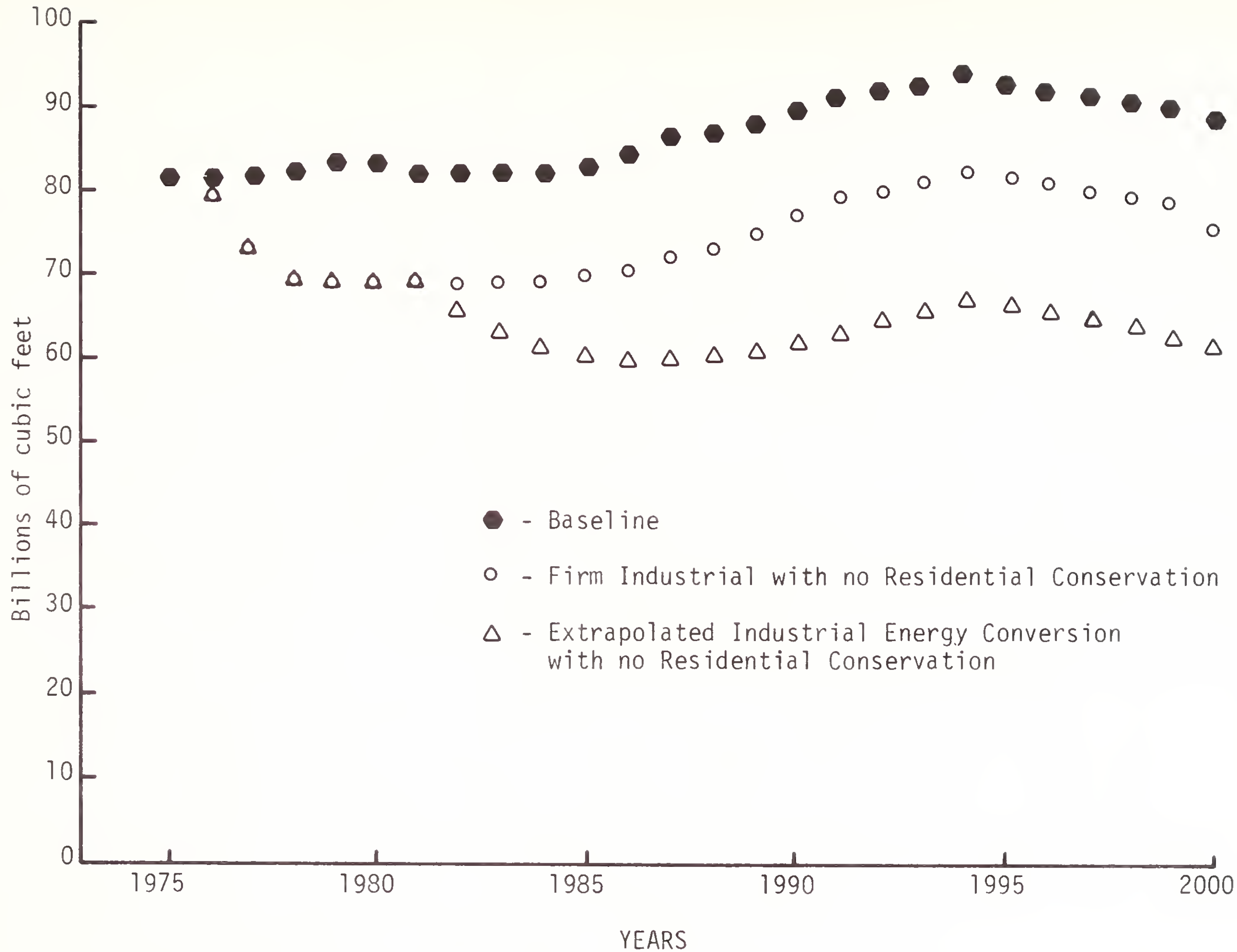

Figure 3.--Montana Natural Gas Demand

D. Gas Price Effects

After showing the general effects residential gas convation and industrial fuel substitution can have on gas demand, the SNG study group used several gas price scenarios to determine a range of possible gas demand in Montana. Gas demand curves shown so far have assumed a rise in gas prices from the current level to $4.50/MCF in the year 2000.

Three price scenarios were selected as representative of low, medium, and high gas prices. Prices are for residential gas use; industrial gas prices were assumed to be lower by $.50/MCF. Figure 4 illustrates the gas demand expected at the specified price levels. Also shown on the graph are the baseline demand and a curve representing the effects of firm industrial fuel substitution (no residential conservation or extrapolated fuel substitution after 1980). Prices assumed for the low, medium, and high gas prices are shown in Figure 5. Table 1 summarizes the results shown in Figure 4.

E. Conclusions

Natural gas demand in Montana (including demand for SNG) will decline from the present level of about 80 billion cubic feet per year to 50-70 billion cubic feet per year by the year 2000. The decline in gas demand after 1980 is caused primarily by projected increases in the gas price to consumers. Even for modest increases in price (to $3/MCF in the year 2000), the deamnd is reduced by about 30% from current demand. A price of $3/MCF by the year 2000 is an average price growth rate of only about 2.5% per year. An average price growth

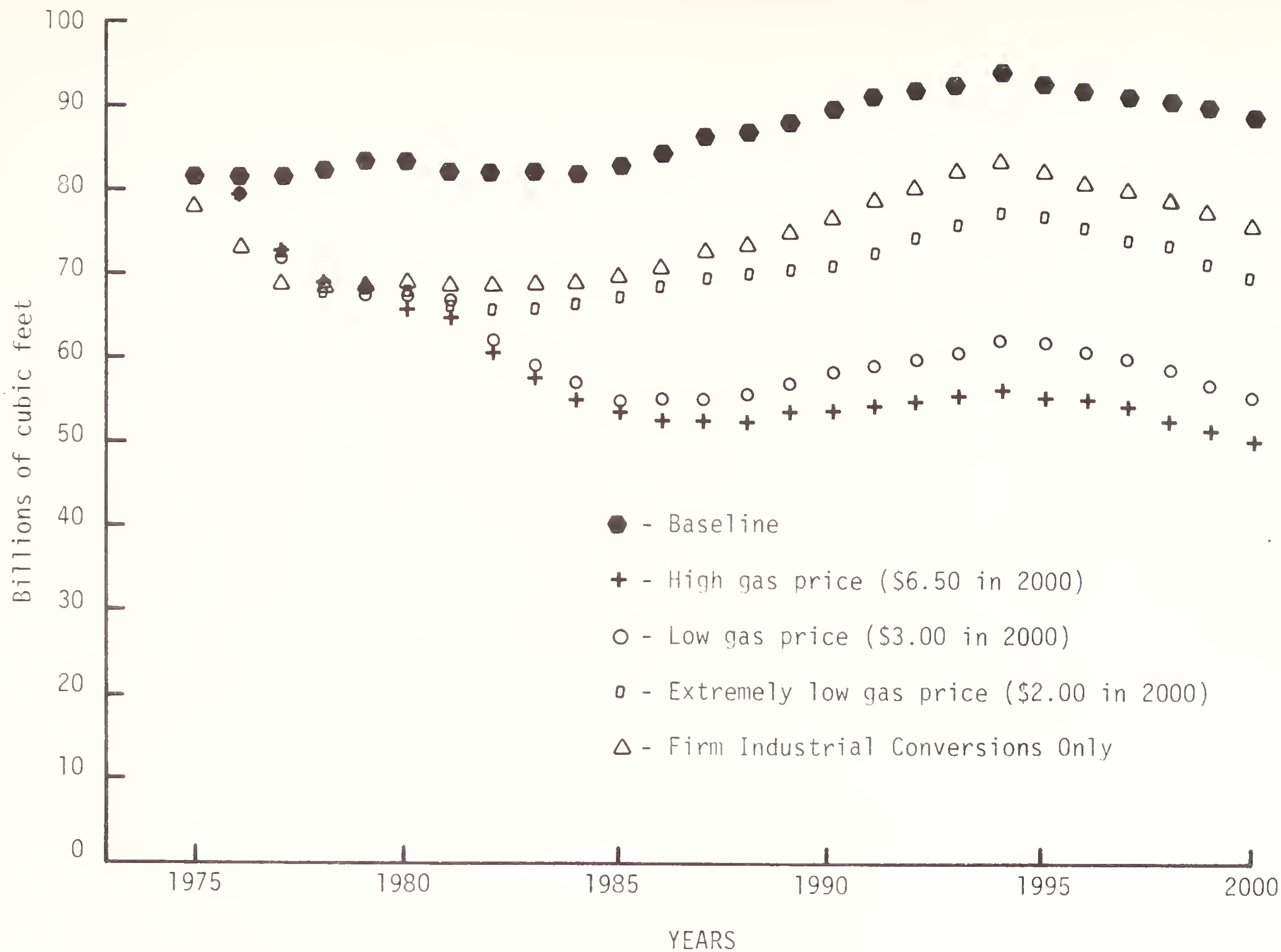

Figure 4.--Montana Natural Gas Demand

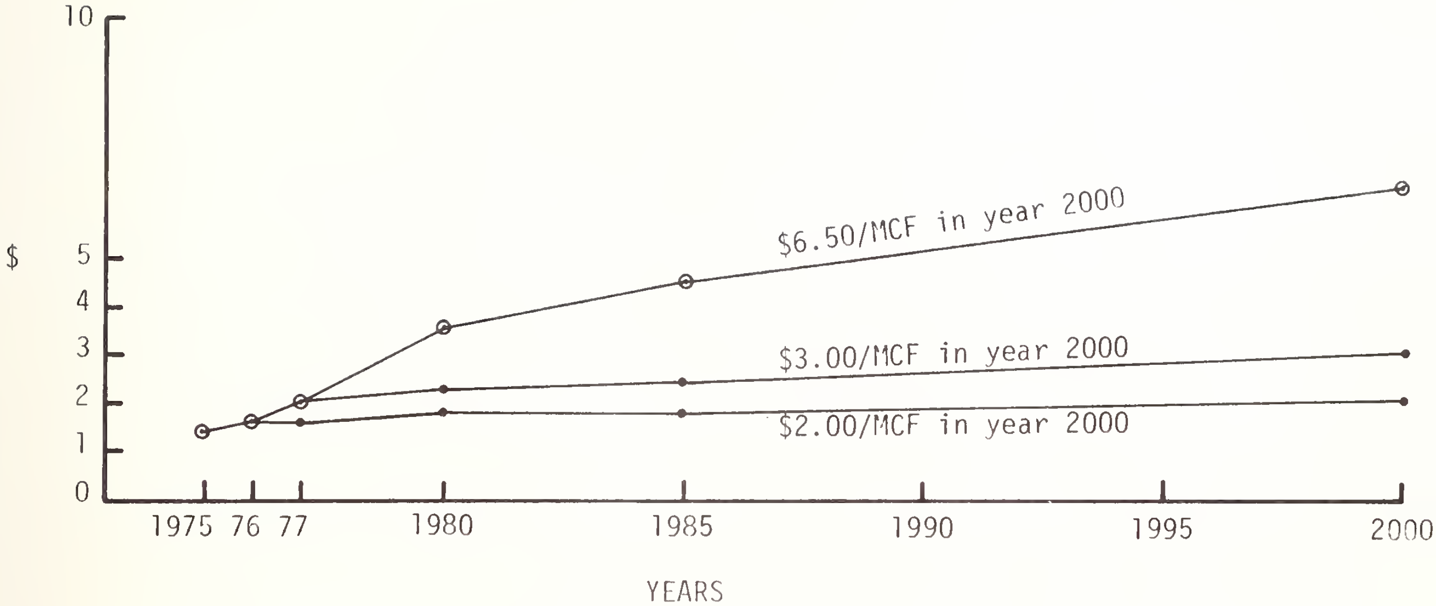

Figure 5.--Natural Gas Price Scenarios

Table 1.--Natural Gas Demand Level (billions of standard cubic feet)

Year	PRICE Low ($2.00 in 2000)	Medium ($3.00 in 2000)	High ($6.50 in 2000)
1980	67	67	66
1985	67	56	54
2000	69	55	51

rate of 5.75% (price goes to \$6.50/MCF in 2000) will drive gas demand down to about 60% of current levels by the year 2000.

It should be noted that the natural/synthetic gas demand projections shown here are probably maximum or "upper bound" estimates. Inter-fuel substitution for heating in the residential and commercial sectors was not modeled, nor was conservation in the commercial sectors. As the price of natural/synthetic gas increases in the future, these factors may become important and hence the demand for natural gas would be lower than that reported here. Unfortunately, the impact of these variables cannot be quantified at the present time.

Although we project a decreasing gas demand, our "most likely" projections still indicate a Montana natural/synthetic gas demand approaching 55-60 billion cubic feet per year in the year 2000.

IV. COMPETITIVE SUBSTITUTE AND SUPPLEMENTAL ENERGY FORMS

A number of substitute energy forms which are or could be competitive with natural/synthetic gas were identified in the course of this study. Only in a few industrial processes is gas actually needed. Natural/synthetic gas is primarily used as a source of heat or as a boiler fuel. Other energy forms can certainly be substituted for natural gas although they may not be as convenient or clean burning.

Both supplemental natural/synthetic gas supplies which could be utilized in the current natural gas delivery system and fuels requiring new energy delivery systems were identified and evaluated. Our inter-fuel substitution research focused primarily on the industrial sector in Montana since significant fuel substitution is currently ongoing in that sector and more is expected. Industries also require quantities of energy sufficient to make the utilization of new fuel delivery systems particularly attractive.

It was realized early that coal could be synthesized into substitute natural gas which could be delivered through existing pipelines and combusted in existing furnaces and burner heads without modification. Detailed technical and economic evaluations of the various processes for producing synthetic natural gas are being evaluated elsewhere.

Several additional supplemental sources of natural gas were also identified. As the price of natural gas increases,

Montana natural gas producers expect to be able to discover and produce more natural gas than in the recent historic past when natural gas prices were constrained to artificially low levels. Similarly, natural gas exploration is expected to increase in Montana's neighboring states. Montana could conceivably receive additional supplies of natural gas from these sources; however, neither the quantity nor the price of these additional supplies can be determined accurately at the present time.

A major reason for Montana's potential natural gas supply shortfall is a projected curtailment of natural gas supplies which are currently imported from Canada. Montana Power has the right to import 34.2 billion cubic feet (BCF) of natural gas from Canada during the year which will end May 13, 1977. They then expect to import 29.2 BCF annually until 1985. Under current circumstances Canadian gas will be completely eliminated by about 1989.[4] It is impossible to assess what the Canadian government may or may not do in the future. Large reserves of natural gas may exist in the Canadian Arctic which could be developed in the future. Based on current policies, however, it seems unreasonable to expect that additional supplementary gas supplies from Canada will become available to Montana.

Large reserves of natural gas are also known or believed to exist in the state of Alaska. These reserves are expected to be developed in the near future with the first gas supplies from this source possibly reaching the continental United States by 1982. Several routes have been suggested to bring

these supplies to the Continental United States and the matter is currently before the Federal Power Commission. Routes under consideration include pipelines through Canada along the Alcan Highway or down the MacKenzie Valley or a pipeline entirely through Alaska with Liquified Natural Gas (LNG) transport from Alaska to the Continental United States. Montana Power currently has an option to purchase 15 BCF of this gas annually.[5] However, the price of this gas may be $3/MCF or higher. The United States could also import LNG from foreign producers; but, this gas is also likely to cost over $3/MCF delivered and result in problems of supply security.

Several substitute energy forms which would require new or modified energy delivery systems were also identified. After preliminary review it was determined that low Btu coal gasification, direct coal combustion, and wood or wood waste combustion are possible economic substitutes for natural gas in the Montana industrial sector.

The wood products industry in Montana currently utilizes a large quantity of wood materials for energy generation. It is certainly possible that more could be used in the future. Montana currently produces over 8 million tons of wood logging residue per year which is either burned at the logging site or simply left piled in place.[6] Unfortunately, the long term delivered cost of this fuel is uncertain; and, the detailed assessment required to fully and accurately evaluate the potential for industrial utilization of this energy source was beyond the scope of this study.[7]

The direct combustion of coal as a substitute for natural gas is an alternative that several industries in Montana have recently turned to. In April 1976 the Ideal Cement Plant at Trident, Montana converted from natural gas to coal at a capital cost of \$2.3 million, or approximately \$1.20 per million Btu.[8] The Kaiser Cement plant near Helena, Montana, has a similar conversion to coal planned for the fall of 1977 at a capital cost of \$1.5 million (∿\$.90/million Btu).[9] Finally, the Great Western Sugar Company in Billings, Montana has announced plans to convert their sugar beet processing plant to coal. The capital cost of this conversion is reported to be \$3.21 million (∿\$2.70/million Btu).[10] Air pollution control costs for this facility are over \$1.2 million. As can be seen above the capital costs of conversion to coal from natural gas are highly variable depending upon the particular industrial facility considered. Normalized conversion costs also vary inversely with the size of the facility converted. Fuel costs for coal delivered in Montana vary with location. Reasonable fuel cost (1975 dollars) estimates for Colstrip, Montana coal delivered to various Montana cities are: Butte \$.70/million Btu; Missoula \$.80/million Btu; Billings \$.50/ million Btu.[11] These coal fuel costs are certainly favorable when compared to natural/synthetic gas. Coal fuel costs do not seem likely to escalate rapidly in the future either.

Coal fired boilers are currently available utilizing either spreader grate or pulverized coal firing. Spreader grate boilers can be employed up to abut 0.5×10^6 lb of steam

per hour; however, the sized coal required for spreader grate operation may not be readily available.[12] Both boiler design and cost are particularly sensitive to the specific type of coal to be used. The Oak Ridge National Laboratory estimates that the annual cost of coal fired steam generation using western coal (8500 Btu/lb, 0.5%S) to be $1.53/million Btu. They also estimate that flue gas cleaning processes are available for $\sim$\$.50/million Btu additional. The Oak Ridge estimate is split almost equally between capital and fuel costs.

The favorable economics of direct coal combustion is somewhat contrasted by its unfavorable environmental impact. Even with the "best available" air pollution control equipment, a coal fired boiler will emitt more pollutants than a conventional gas fired boiler. As previously noted a significant portion of the cost of coal fired boilers will be allocated to air pollution control. Although direct coal fired combustion (with proper pollution control) appears suitable for areas with adequate pollution dispersion potential, there are certain areas within the state (particularly in western Montana) where conventional coal combustion may simply be environmentally unacceptable.

Fluidized bed combustion, a new alternative process for direct coal conversion is currently under development and holds high promise for the future. Fluidized bed combustion is undertaken in an inert bed of coal ash and crushed limestone which rests on a bed of nozzles. Combustion air enters the bed through the nozzles, expanding the bed and causing it

to flow much like a liquid. Combustion is accomplished by introducing crushed coal and raising the bed to the ignition temperature of the coal. Volumetric heat release rates for fluidized bed combustion are on the order of 10 times those of conventional pulverized coal furnaces. Heat transfer surfaces are placed within the bed itself to absorb at least half of the heat released; the remainder of the heat released is collected by conversion surfaces. The combustion temperature of the bed is controlled to 1600-1800°F, considerably lower than conventional coal combustion. Since this combustion temperature is below the ash fusion temperature of coal, fluidized bed boilers can be designed independent of the type of coal to be used.

One of the major attractive features of fluidized bed combustion is its potential for air pollution emission control. Emission control is inherent in the fluidized bed combustion process. If limestone is injected into the fluidized bed, the bed turbulence will promote the reaction of sulfur dioxide with limestone and effectively remove sulfur from the system as dry calcium sulfate. Studies on the potential for limestone regeneration are currently underway.[13] The relatively low combustion temperature is the fluidized bed combustion temperature in the fluidized bed combustion process also limits the formation of oxides of nitrogen as does the minimum of excess air required for combustion.

There are no fluidized bed boilers commercially available in the United States today. A 30 Megawatt pilot fluidized bed

boiler was recently built in Rivesville, West Virginia and is currently beginning to undergo testing.[14] The Foster-Wheeler Company, manufacturer of some of the components of the Rivesville plant, indicate that they will warranty units of comparable size after 6 months of successful operation. The city of Linköping, Sweden is currently evaluating bids from several vendors to build a 15 MW boiler for its district heating system; hence, at-least intermediate sized fluidized bed boilers must be available in Europe.[15] Cost data for fluidized bed boilers are not yet fully developed in the United States. In 1970, Pope, Evans, and Rogers estimated that a fluidized bed boiler would cost approximately 1.4 times that of an equivalent gas fired boiler while a conventional spreader grate coal fired boiler would cost 2.35 times more than a gas fired boiler.[16] Oak Ridge National Laboratory predicts slightly lower steam costs ($1.65/million Btu versus $1.84/million Btu) for a fluidized bed boiler compared to a conventional boiler with stack gas desulfurization at an equivalent location. The lower costs for fluidized bed combustion are projected because of their more compact, standardized design, their reduced surface area, and the fact that they can be factory rather than field assembled. Applications of fluidized bed combustion for residential and commercial use are also being researched. The Montana Energy and MHD Research and Development Institute is particularly interested in a novel fluidized bed furnace that is applicable to home heating uses.

Fluidized bed coal combustion appears to be a particularly useful alternative to natural gas in Montana. While the process is not widely available now it seems to be ready for commercial development and must be considered when evaluating future alternatives. A detailed investigation of its suitability and potential as an alternative energy form appears warranted on the basis of this investigation.

Finally, the potential applicability of low Btu coal gasification in the Montana industrial sector was evaluated. Low Btu coal gasification is essentially the first step in the process of producing synthetic pipeline quality natural gas. Coal is reacted with steam at high temperatures and pressures to produce carbon monoxide and hydrogen. If the reaction occurrs in the presence of air the resultant gas is diluted with nitorgen and has a heating value of approximately 125-150 Btu/cubic feet (SCF). If the initial reaction occurrs in an oxygen atmosphere the heating value of the resulting gas is increased to nearly 300 Btu/SCF. Conversion from natural gas to low Btu gas may require boiler derating and/or burner head modification depending on the exact heating value of the gas produced.

The technology of low Btu coal gasification is well developed. Before natural gas was widely available, low Btu gas (town gas) was used for home lighting and heating and in industrial processes throughout Europe and the eastern United States. There is a single brick manufacturer in Pennsylvania that currently gasifies about 85 tons of coal per day.[17] Worldwide there are many low Btu gasifiers operating. There are

several manufacturers that currently offer low Btu gasification reactors.

Low Btu coal gasification can be considerably cleaner than conventional direct coal combustion. Particulate air pollution control is to a large degree inherent in the gasification process since primarily gaseous products leave the reaction vessel. The gaseous stream is usually further scrubbed to remove most of the remaining entrained particulate matter. Sulfur also can be removed effectively since it will be in the gas stream as hydrogen sulfide. There are a number of commercial processes available to remove hydrogen sulfide; however, because sulfur removal is not inherent in the process, additional costs are incurred for this sulfur removal. Some manufacturers claim that by gasifying low-sulfur coal they can meet applicable federal air pollution regulations without sulfur removal. This tactic is probably inappropriate for Montana industry since many of the industries which could utilize low Btu gasification are in areas where ambient air quality standards are already approached or exceeded.

Several cost estimates for low Btu gasification have recently been developed. Low Btu gasification should inherently be cheaper than producing pipeline quality synthetic natual gas since neither the water gas shift reaction for relative hydrogen enrichment or methanation are required. Low Btu gasification facilities are also generally located at the load center so that gas transportation costs are minimized. Unfortunately, most recent reviews indicate that low Btu gas will

cost in the range of $3.00-$4.00/million Btus.[18,19] Costs increase as the size of the facility decreases. However, a number of sources still do predict that low Btu gasification will be less expensive than pipeline quality synthetic gas production.

In summary one can identify a number of supplemental or substitute energy forms which are applicable to Montana. These supplements or substitutes will all be much more expensive than natural gas historically has been. Some of these substitutes/supplements will undoubtedly be utilized in the future; however, their high costs signal that conservation will also have a significant impact on the future demand for natural/synthetic gas in Montana.

ACKNOWLEDGEMENTS

Our special thanks go out to the many individuals and organizations who have aided this project. Particular appreciation is extended to the people of the Montana Department of Community Affairs, the Montana Energy Advisory Council, the Montana Power Company, and the Willamette Simulation Unit.

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6. Coldiron, W. H., Letter to Montana's Lieutenant Governor, Bill Christiansen, Helena, Montana. May 1976.

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10. Montana Standard, April 9, 1976, p. 9.

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15. Ibid.

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APPENDIX A

Narrative Description of the Montana Dynamic System Simulation Model

This appendix is divided into sections as follows:

Section A-I, Overview of the Model

As in many other regions of the country, the supply of natural gas in Montana may not be sufficient to meet future needs. One method to avoid this problem in Montana is to produce SNG (synthetic natural gas) using the extensive coal reserves. The purpose of this study is to determine the demand for SNG in Montana.

Determining the demand for SNG is essentially a balancing problem. The SNG demand is the additional production required to balance natural gas requirements with the supplies available. Thus, the demand for and supply of natural gas must be determined before the demand for SNG can be found. Natural gas cannot be considered alone as it competes with other fuels. Major conversion of industry gas uses to coal and electricity are certainly possible and can significantly affect the demand for natural gas. The cost of producing SNG is likely to be different from the natural gas obtained from conventional sources. Thus, the part of the demand filled by SNG may be complete at different price levels than other natural gas.

The approach used here was to develop a model of Montana's economy on which energy demands can be based. The overall structure is shown in Figure 1. The industrial and commercial demands for energy are based upon the levels of activity in the corresponding sectors of the economy while residential demands are based upon the number of households and their income. In addition, the effects of inter-fuel competition and conservation are considered.

The model is similar in concept to the Oregon State Simulation Model (1) and the structure of some of the sub-models is basically the same as in their Oregon counterparts. The Montana Futures Project input-output model (2) is

also used in the formulation of the model. The primary modeling technique used is dynamic systems simulation.[3] This methodology deals with the forces causing change in the economy and should be well suited for the transients which are likely in Montana's future. It also allows the model to be based more closely on the actual processes and actions which occur in Montana's economy. The dynamic simulation is combined with input/output analysis in determining levels of economic activity. The use of the input/output analysis assists in obtaining more detail in this critical area.

Each sub-model is discussed separately in the following sections. An effort has been made throughout to design the models such that they can easily be improved as additional information becomes available. In this manner, major model changes will not be required when better data are obtained.

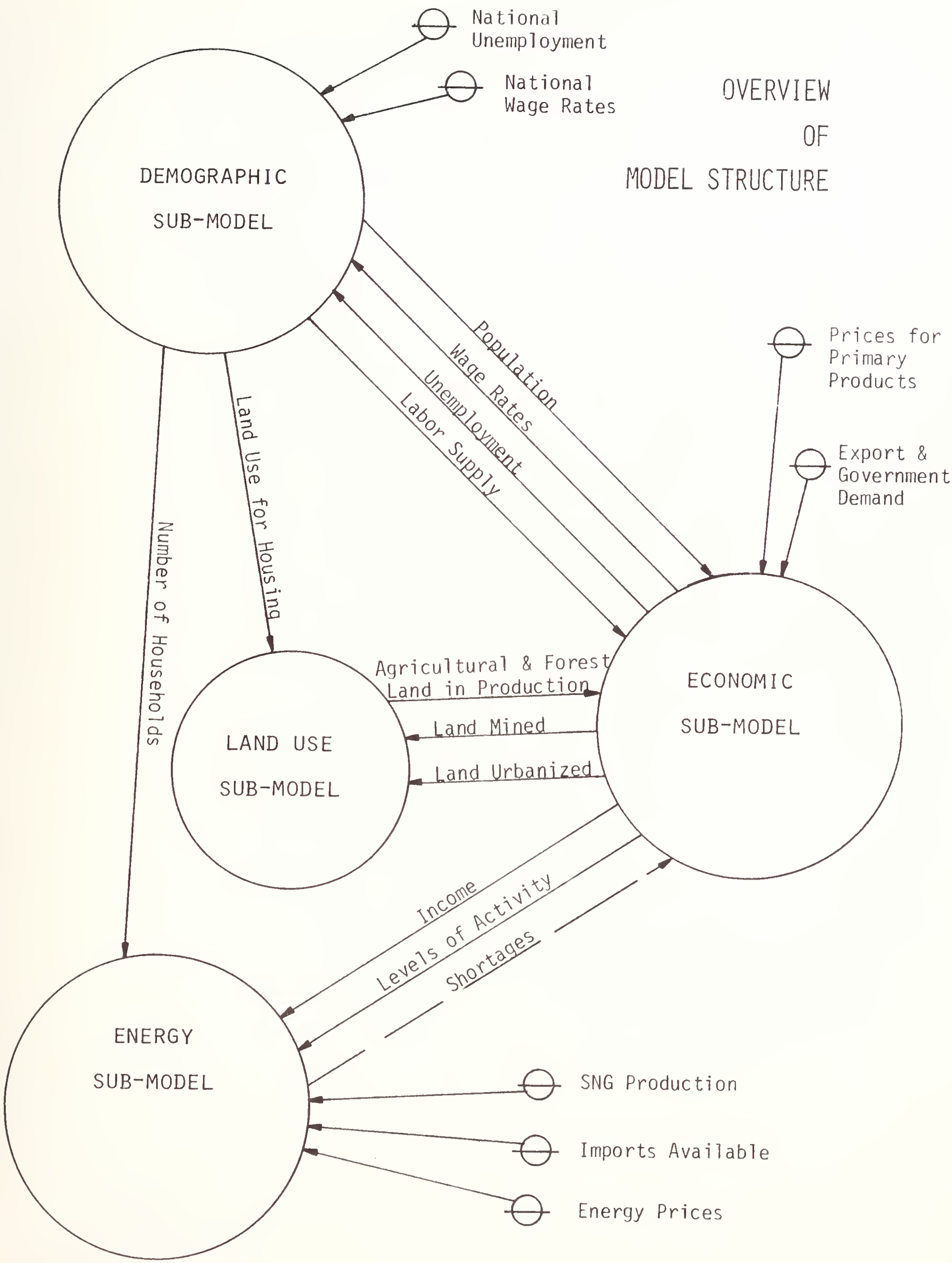

National Unemployment
National Wage Rates
OVERVIEW OF MODEL STRUCTURE
DEMOGRAPHIC SUB-MODEL
Population
Wage Rates
Unemployment
Labor Supply
Prices for Primary Products
Export & Government Demand
Land Use for Housing
Number of Households
Agricultural & Forest Land in Production
Land Mined
Land Urbanized
LAND USE SUB-MODEL
ECONOMIC SUB-MODEL
Income
Levels of Activity
Shortages
ENERGY SUB-MODEL
SNG Production
Imports Available
Energy Prices

Figure 1

Overview Model References

1. Oregon State Simulation Model, Willamette Simulation Unit, Oregon State University.

2. Montana Futures Project, Division of Research and Information Systems, Department of Community Affairs, State of Montana.

3. J. W. Forrester, Industrial Dynamics, The MIT Press, Cambridge, Massachusetts, 1961.

Section A-II, Demographic Sub-Model

The demographic sub-model predicts the number of people that will be in Montana and the number of households in the state. The projections are based upon current population and predicted net migration. The migration is affected by the difference between Montana unemployment levels and national unemployment levels.

Demographic Sub-Model References

1. "General Housing Characteristics," 1970 Census of Housing, advance report, U.S. Department of Commerce.

2. "1974 Montana Vital Statistics," State Department of Health and Vital Statistics, Helena, Montana.

3. "General Population Characteristics," 1970 Census of Population, U.S. Department of Commerce.

4. "General Population Characteristics," 1970 Census of Population, advance report, U.S. Department of Commerce.

5. "Vital Statistics of the United States," 1971, U.S. National Center for Health Statistics.

Section A-III, Land Use Sub-Model

The land use component maintains a current inventory of land in each of six categories. The following description details the flow between categories.

Residential and commercial-industrial land is directly converted from agricultural land. The demand for residential land is quite different from the demand for commercial-industrial land due to the relative intensities of use. Demand for residential land is driven by the demographic component. This rate is a function of the rate of household formation and the residential conversion density. In mathematical form the change in demand for residential land is given by:

$$\Delta DEM_R = \Delta HH \div CD$$

where DEM_R is demand for residential land, HH is the number of households (from demographic component), and CD is the conversion density ($\frac{\text{total households}}{\text{total residential acres}}$).

The commercial-industrial (C-I) land use demand is generated in the levels of activity in the industrial sectors of the economic component. The rate of demand for the C-I land is determined by the rate of employment and the employees/acre in the C-I sectors. In mathematical form:

$$\Delta DEM_C = \Delta EM_C \div EA$$

where DEM_C is demand for C-I land (acres), EM_C is employment in C-I sectors, and EA is $\frac{\text{total employees in C-I sector}}{\text{total acres in C-I land}}$.

The demand for residential and C-I land is summed to obtain the total land converted from agricultural to urban land. In mathematical form:

$$\Delta DEM_T = \Delta DEM_C + \Delta DEM_R$$

where DEM_T is total urban land demanded.

The mining land is directly converted from agricultural land, since the stripped land in Montana is almost all used for crops or grazing. The conversion rate is a scenario variable derived from standard coal production per year. The land mined per year is calculated by dividing the tons of coal produced by the tons of coal per acre.

Mined land converts to waste land or reclamation land. The stripped land which falls into the reclamation land category is revegetated over a period of years. The time span is a technical policy input. Waste land is derived from the product of land mined and fraction of revegetation, this fraction being a technical policy input.

Forest land use accounts for all the land upon which commercially harvestable timber is growing. Agricultural land can be converted to forest land; however, in Montana this is unlikely. Policy input for reforestation is 0.

Wilderness land is an area which can be converted from forest land to preservation status by a policy input. This relationship can also be reversed, wilderness land converted to forest land.

LAND USE DATA

Land Use (1,000 Acres)	1967
Agricultural Land (5)	62,900
Forest Land Total (2)	18,805
Wilderness (3)	2,145
Logging	16,660
Urban (2)	818
Mining*	4
Other (waste) **	10,562
TOTAL LAND AREA	93,089

Coal Mined = 11 x 10^6 tons/yr (1973) (4)

Tons/Acre = 28320 T/A. ***

Residential Land = 613,500 (assumed 75% of Urban) (3)

Industrial Land = 204,500 (assumed 25% of Urban) (3)

Households/Acre = .354 (4)

Employees/Acre = .2396 (4)

Total Households = 217,300 (4)

Total Employees (non farm) = 49,000 (4)

* Mining Land = (acres mined in last 10 years)

** Other land = Total land - (Agriculture Land + Forest Land + Urban Land + Mining Land).

*** Tons/Acre = 11 x 10^6 tons/yr[5]/1416 tons/acre ft (.8 recovery[7]) (25 ft average coal seam[8]).

LAND USE

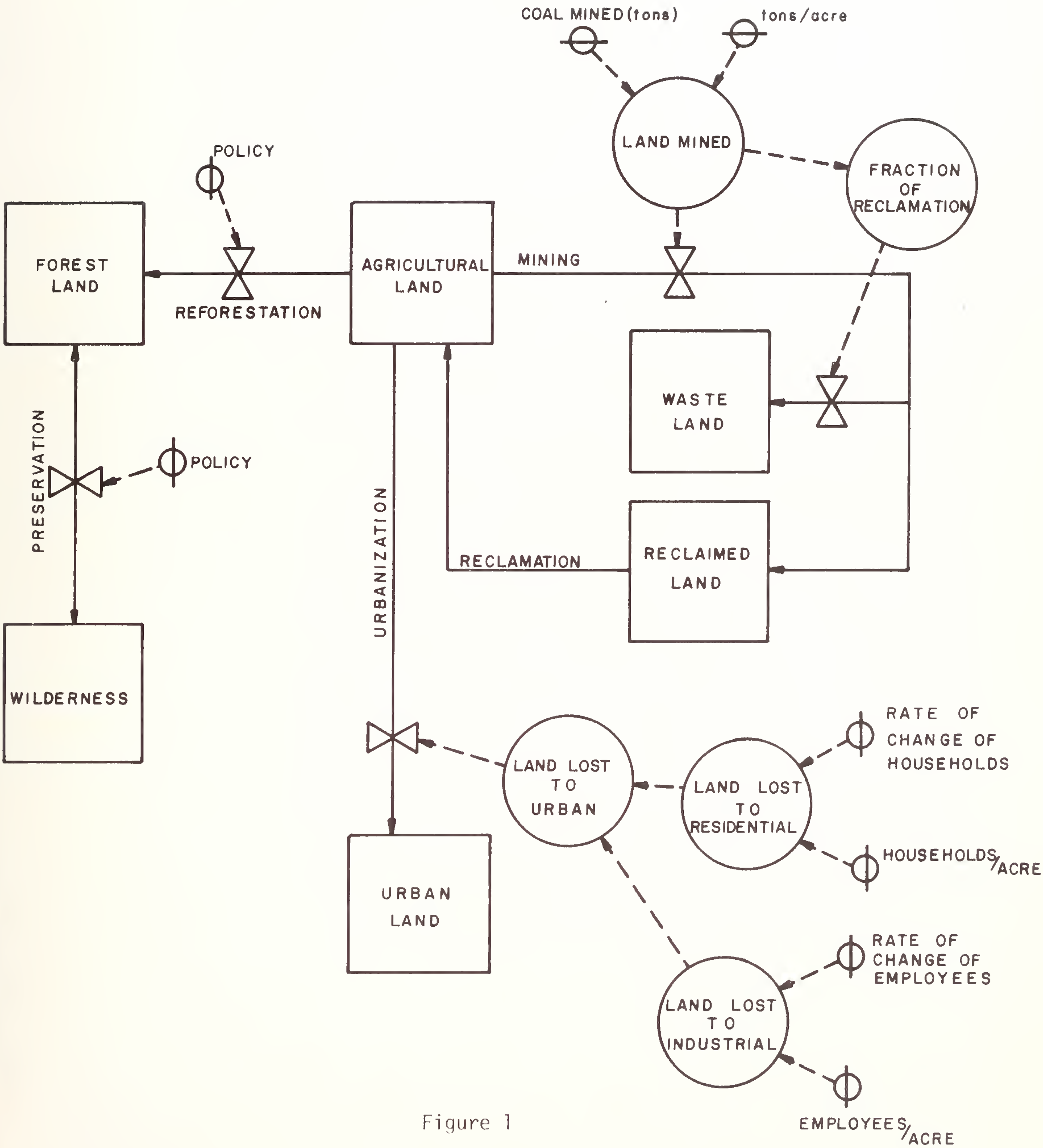


Figure 1

Section IV, Economic Sub-Models

The economic sub-model is structured as shown in Figure 1. Five separate sectors are used for the primary activities: agriculture, forestry, coal mining, oil and gas production, and non-energy mining. Since the output of the petroleum refining, and primary metal processes depends mainly on the amount of oil produced and metal mined in Montana, they are also considered separately. This part of the model can be considered supply limited. The output of these sectors plus consumer expenditures, export demands, government spending, and capital expenditures, drive an input-output model for the rest of the economy. These activities can be considered demand limited. The outputs are then used to determine total employment and income.

Each of the sectors for the primary activities and for petroleum refining and primary metal processing are modeled separately. The capital investment and employment models are also discussed.

ECONOMIC MODEL

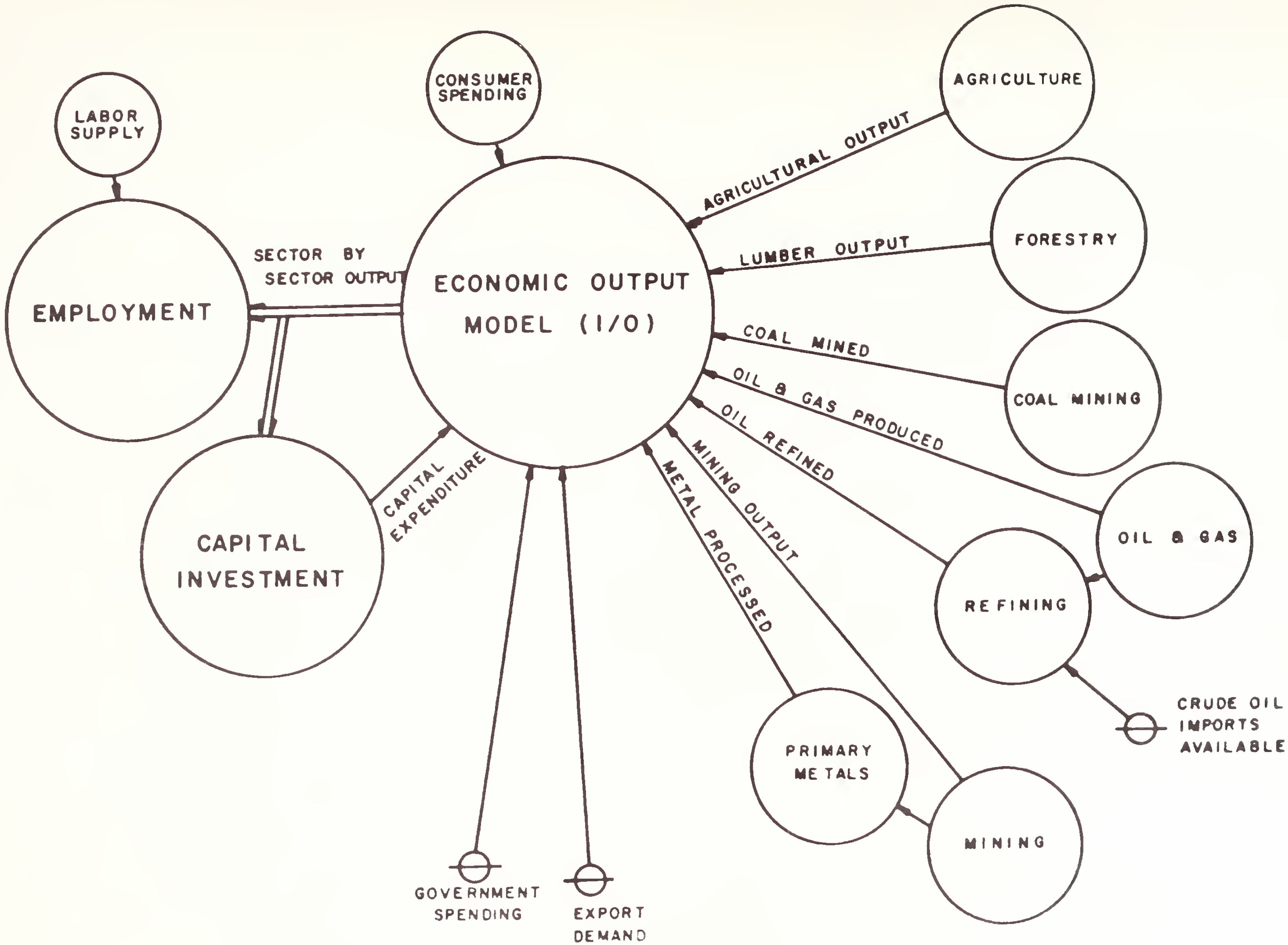


Figure 1.--Overall Structure of the Economic Sub-Model

Agricultural Sector

The agricultural sub-component of the economic model is divided into two parts, agricultural production and capital formation.[1] Figure 1 illustrates the interrelationship between the two parts and how each interfaces with the rest of the model.

Agricultural Production: The amount of agricultural land and the level of capital employed are combined, utilizing a modified Cobb-Douglas production function, to generate the production level.[2]

$$Y = A \times TK^{ALP} \times AL^{(1-ALP)}$$

where Y = Agricultural production; total annual market value of farm products sold (in constant dollars).

TK = Agricultural capital; total value of machinery and equipment employed as a factor of production.

AL = Agricultural land.

ALP = Parameter: relative importance of capital as compared to land.

A = Constant relating units of capital and land to units of production.

Gross production in dollars is a function of Ag output in constant dollars and relative price (P) of Ag products.

$$D = YP$$

The remainder of the production model converts gross agricultural production to net farm recipts by subtracting the aggregate expenses incurred in production. The production expenses, all measured in 1970 dollars/yr, fall into four categories: direct operating expenses, labor expense, interest expense, and property tax expense. Direct operating expenses (DOE) include the cost of livestock and poultry, feed and seed, fertilizer and other chemicals, petroleum fuels and electricity, machine hire, irrigation and miscellaneous farm services. Direct operating expenses are assumed to be a fraction of the gross production:[2]

$$DOE = (Y) \times OP$$

where OP = operating expense fractional multiplier.

The labor expense (ALE) is the cost of hired labor. It is calculated by multiplying the labor demand by the average annual wage rate:

$$ALE = WR \times (Y \div OPL)$$

where OPL is the output/labor ratio ($/man year).

The interest expense (EI) is the sum of interest on the aggregate farm mortgage debt and interest paid on financial capital:

$$EI = (R \times AKF) + (PLF \times AL \times PL \times R)$$

where

R = Annualized interest rate.

AKF = Level of financed capital stock ($).

PLF = % of agricultural land mortgaged.

PL = Average value of agricultural land ($/acre).

The property tax expense (ET) is the product of the average farm property tax rate (FTR) and the average value of agricultural land:

$$ET = FTR \times AL \times PL$$

The Net Farm Receipts (ANFR) are then determined by reducing the value of gross agricultural output by the sum of the aggregate expenses incurred:

$$ANFR = PY - (DOE + EI + ET + ALE)$$

Capital Formation: The value of machinery and equipment employed in Montana's agricultural sector has greatly increased in the past two decades. Unfortunately, due to exogenously imposed variations that are beyond their control, farmers are generally forced to allocate their resources under conditions of imperfect knowledge of the future.[1] Considerable uncertainity exists concerning the success of future crops and the market prices of

agricultural commodities. There seems to be a tendency for the agricultural sector, as a whole to over-capitalize in an attempt to maximize production, with the attendant increased costs of production offsetting the increased gross farm sales. Hence, net farm receipts have failed to keep pace with the steady rise in productivity.

The capital formation model starts with the value of net farm receipts developed in agricultural production and determines the resulting change in capital. If net farm receipts are greater than zero, a portion is used to purchase new capital. Depreciation of capital stock is assumed to occur at a rate that is proportional to the installed level. The change in the level of owned capital stock (AKO) is given by:[2]

$$\Delta AKO = [(ANFR \times PTI) - (AKO \times AKDEP + DI)] \times DT$$

where PTI = propensity to invest; scenario input with default assumption that investment is a linear function of net farm receipts.

AKDEP = proportional rate of depreciation scenario variable.

DI = Disinvestment.

It is also assumed that farmers in the aggregate tend to increase the sector's level of capital stock by borrowing. Conventional financing (cash down payment, with the purchased capital acting as collateral) allows the sector to "leverage" their available cash. In addition, there is reason to believe that the farm community has utilized the deferred annual capital gain on agricultural land to help finance capital investment. The change in the level of financed capital stock (AKF) is given by:[2]

$$\Delta AKF = [(ANFR \times PTI \times ALEV1) - (AKF \times AKDEP)] \times DT$$

where ALEV1 = leverage on cash, policy input that accounts for the addition to capital made possible by using capital as collateral.

In the event net farm receipts are less than zero, disinvestment can occur. If the magnitude of the loss exceeds a specific fraction of gross production (TF), it is assumed that the agricultural community will be forced to further reduce the level of owned capitol stock by liquidating it at its salvage value; otherwise, capital is simply allowed to depreciate without replacement.[2] If NFR(t) >TF(Y), then

$$\Delta AKO = [NFR + TF(Y)] / salv - AKO(t-1)\ AKDEP$$
$$\Delta AKF = AKF(t-1) \times AKDEP$$

However, if NFR $\leq$ TF x Y , then

$$\Delta AKO = -AKO(t-1) \times AKDEP$$
$$\Delta AKF = -AKF(t-1) \times AKDEP$$

Notes:	Reference
Direct operating expense/unit output $435 \times 10^6/644 \times 10^6 = 0.675$	(4)
Hired labor/unit output 11000 man yrs./$\$644 \times 10^6 = 17.1$ man yrs./$10^6\$$	(3)
Wage rates = $3,363/yr	(*)
Property tax rate Total tax/(total land x value) $35.7 \times 10^6/(62.9 \times 10^6 \times \$60) = 9.46 \times 10^{-3}$	(3)
Value of land $ 60/acre (1969) $150/acre (1976 estimate)	(4)
Interest rate 0.06	(Assumed)
Fraction loss allowed 0.20	(Assumed)
Salvage value 0.30	(Assumed)
Propensity to invest 0.20	(1)
Leverage on cash 1.00	(1)
Total capital $\$420 \times 10^6$ (non land) $\$210 \times 10^6$ (owned capital) $\$210 \times 10^6$ (financed by leverage on cash)	(4)
Fraction of Land Mortgaged .06	(**)
Depreciation $\$97.2 \times 10^6$/yr	(3)

* Wage rate was obtained by dividing total expense for hired farm labor[4] by total labor[3].

** Fraction of farm land mortgaged was obtained by the following relationship:

$$F = \frac{\text{Total Interest Payments}^{3} - \text{Financed Capital} \times \text{Interest Rate}}{\text{Total Land}^{4} \times \text{Average Land Value}^{4} \times \text{Interest Rate}}$$

Notes:	Reference
Production function	
$A = 6.994$	
$ALP = .2$	(***)
Depreciation Rate	(5)
.077	

*** ALP was arbitrarily set at 0.2. The value for A was then calculated from:

$$Y = A \times TK^{ALP} \times AL^{(1 - ALP)}$$

POLICY/SCENARIO INPUTS

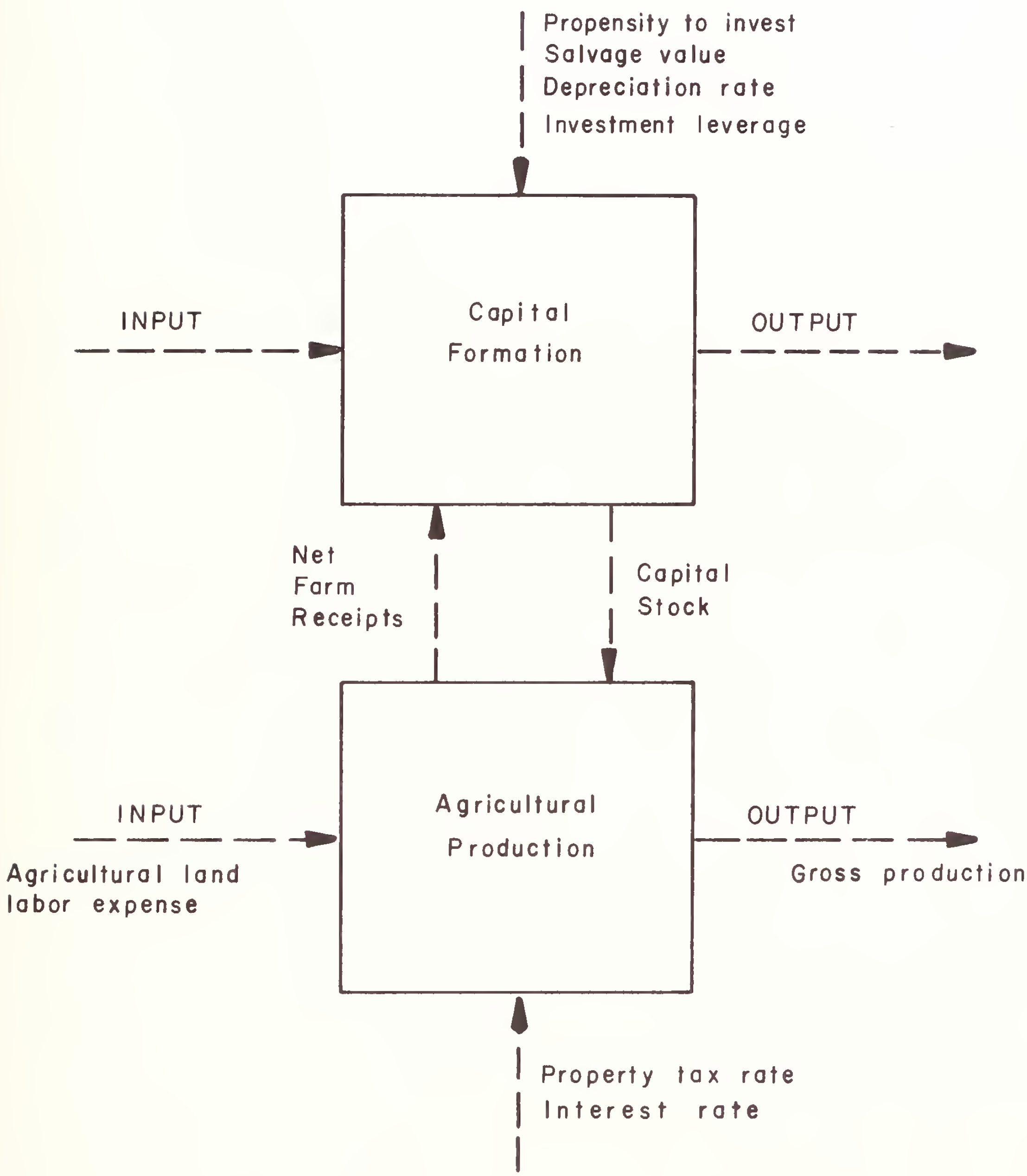


Figure 1

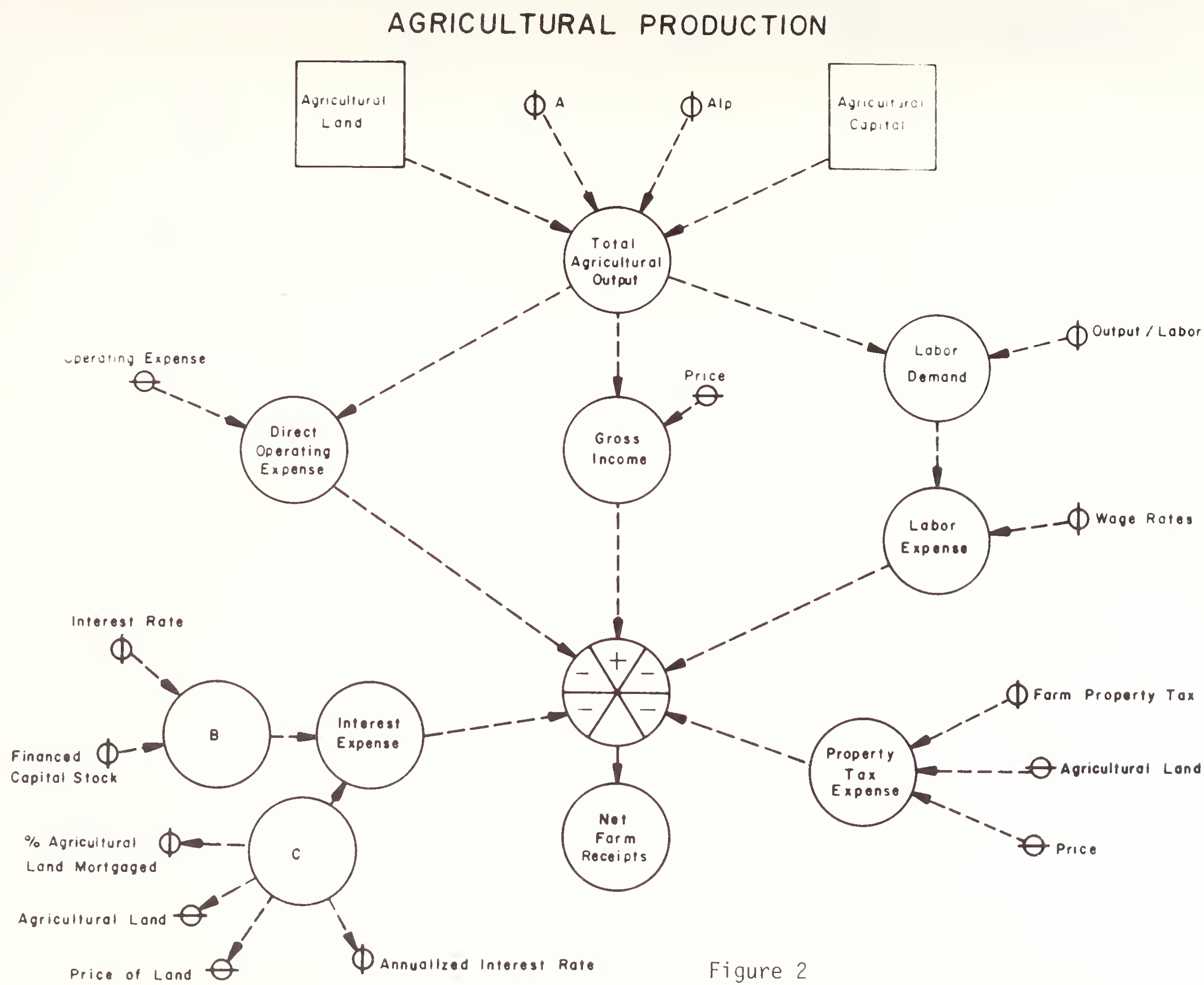

AGRICULTURAL PRODUCTION
Agricultural Land
A
Alp
Agricultural Capital
Total Agricultural Output
Operating Expense
Direct Operating Expense
Gross Income
Price
Labor Demand
Output / Labor
Labor Expense
Wage Rates
+
−
−
−
−
Interest Rate
B
Financed Capital Stock
Interest Expense
C
% Agricultural Land Mortgaged
Agricultural Land
Price of Land
Annualized Interest Rate
Net Farm Receipts
Property Tax Expense
Farm Property Tax
Agricultural Land
Price

Figure 2

CAPITAL FORMATION

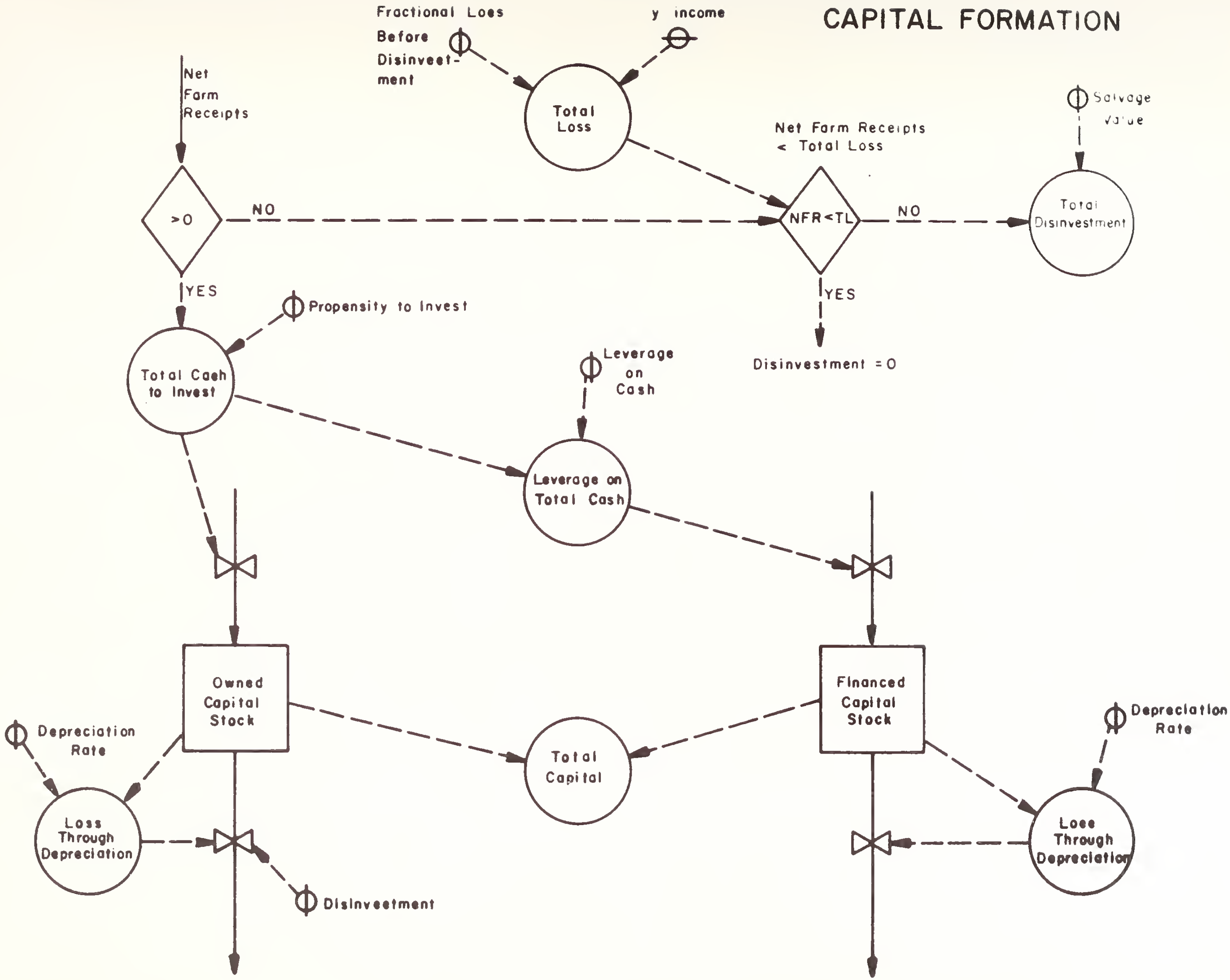


Figure 3

Forestry Sector

The principal assumption in the forestry sector is that Montana's economy is driven in the long run by the projected inventory of standing mature sawtimber available to be cut in each year.[1] The total capital (TCR) to harvest the allowed timber cut is adjusted by technology and the future capital required. Additional capital (ACN) is a relationship between the total capital required and the present level of capital (CAP) [a function of depreciation (DEP) and the capital formation rate (CFR)]. In mathematical form:

$$\Delta CAP = CAP + (CFR - DEP)$$
$$ACN = TCR - CAP$$

where

$$\Delta CFR = (ACN/CT) + DEP$$
$$CT = \text{investment closure time}$$

The annual cutting rate is then determined by calculating the difference between the standing timber available to cut and the maximum possible cut given the current level of installed capital.

The structure of the model is shown in Figure 1.

FORESTRY MODEL

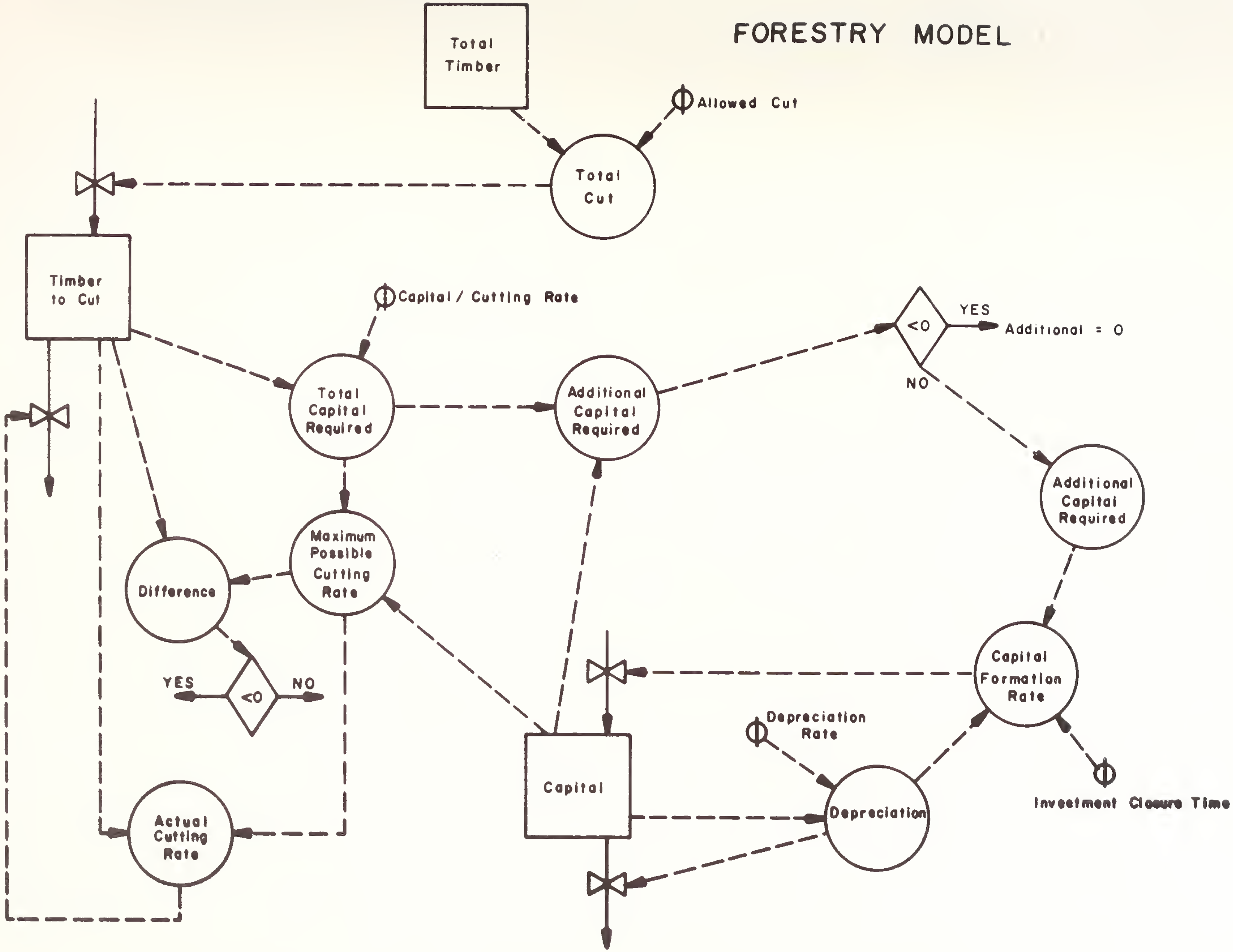


Figure 1

Notes:

1.

Year	Capital Formation	Employees	Growth Rate
1967	$\$6.4 \times 10^6$	$8.5/10^6\$$	
			1%
1963	$\$9.8 \times 10^6$	$8.3/10^6\$$	
			4%
* 1958	$\$6.8 \times 10^6$	$6.7/10^6\$$	
			2%
1954	$\$6.7 \times 10^6$	$6.2/10^6\$$	
	7.4 million/yr. Average		2.5% Average

2. 361.3×10^9 BF Total Timber
1336 Board Feet $\times 10^6$ Timber Harvest 1963 (2)

3. depreciation 6.7% yr. (assumed)

4. capital investment = actual capital (depreciation + growth rate)

$$AC = \frac{7.4 \times 10^6}{.092} = \$80 \times 10^6 \text{ actual capital, 1963 **}$$

5. capital needed to cut 1 BF/yr. = actual capital/timber harvest
.06 $BF/yr.

* "Forest Industries," Montana Data Book, Chapter 9, Montana Department of Planning and Economic Development, State of Montana, 1970.

** 0.092 is the depreciation rate plus the average growth rate.

Coal Mining and Non-Energy Mining Sectors

The sectors for coal mining and non-energy mining are similar in structure. Only some parameters are different. For the sake of simplicity, they will be discussed together here.

Figure 1 shows the structure of the non-energy mining sector. The total quantity which has been mined is used to determine the productivity or cost for mining. The mining cost function relates the average variable production cost per ton of output to the total mined. The capital cost function relates the investment required for a given rate of output to the total mined. The actual output is limited by the total existing investment. It may also be limited by the product price. The cost distribution function describes the distribution of cost for different levels of output. If the price is divided by the average cost then this function can determine what fraction of the total possible output is economical. This is then used to determine the actual output.

The total output is multiplied by the product price to determine mining income. The average cost is modified by integrating the cost distribution function over the fraction actually produced to obtain a multiplier. The result is multiplied by the actual output to determine the mining expense. The capital expense is determined by assuming the capital investment is amortized over a 20 year time period at a specified interest rate. The expenses are subtracted from the income to determine the profit rate and the rate of return. The investment function determines the rate of investment from the rate of return.

For non-energy mining, most ore deposits (copper in particular) are most easily mined at a limited rate. Higher production rates are attained

NON-ENERGY MINING MODEL

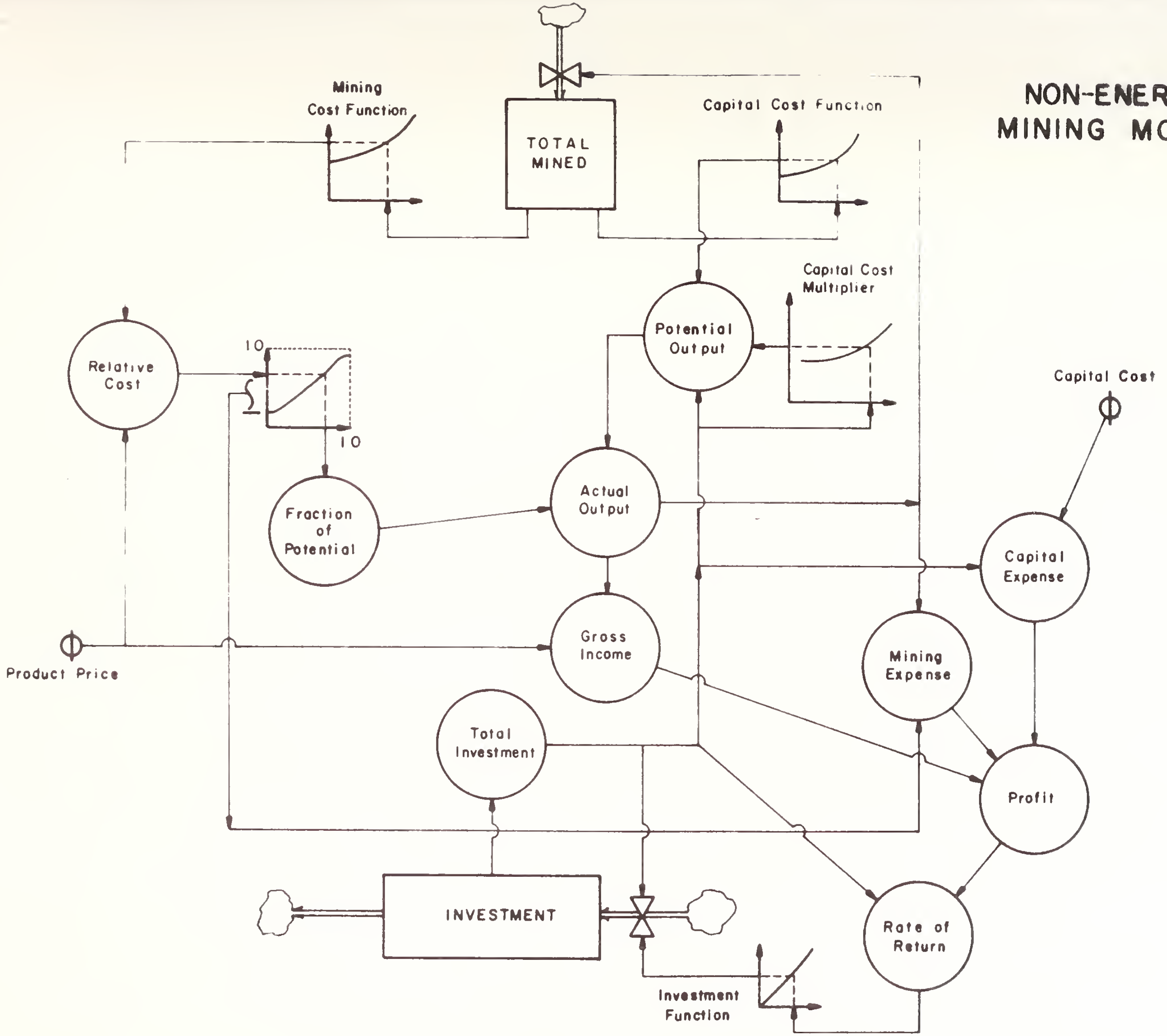


Figure 1

only with increased cost per unit of output. This is simulated in the non-energy mining sector by making output capability a non-linear function of total investment.

The model for the coal mining sector of Montana's economy is shown in Figure 2. Since Montana has large coal reserves (even in comparison to total United States coal demand) over production and market saturation could conceivably occur. This would tend to depress the selling price of the coal. The effect of market saturation is simulated by determining a price for the coal being produced. An exogenous market level indicates the size of the market that is available before any saturation takes place. If more coal is produced than can be sold on this market, the price of coal is decreased. If the coal production then falls off to a level that is less than the market saturation level, the coal price will return to a normal value.

In a growing, profitable industry, such as coal mining is in Montana, there will undoubtedly be new companies entering the industry. Thus, new investment will come not only from the profits of the industry, but also from other sources. The additional investment is simulated as being proportional to the expected rate of return and the difference between current production and the production level that would saturate the market.

COAL MINING MODEL

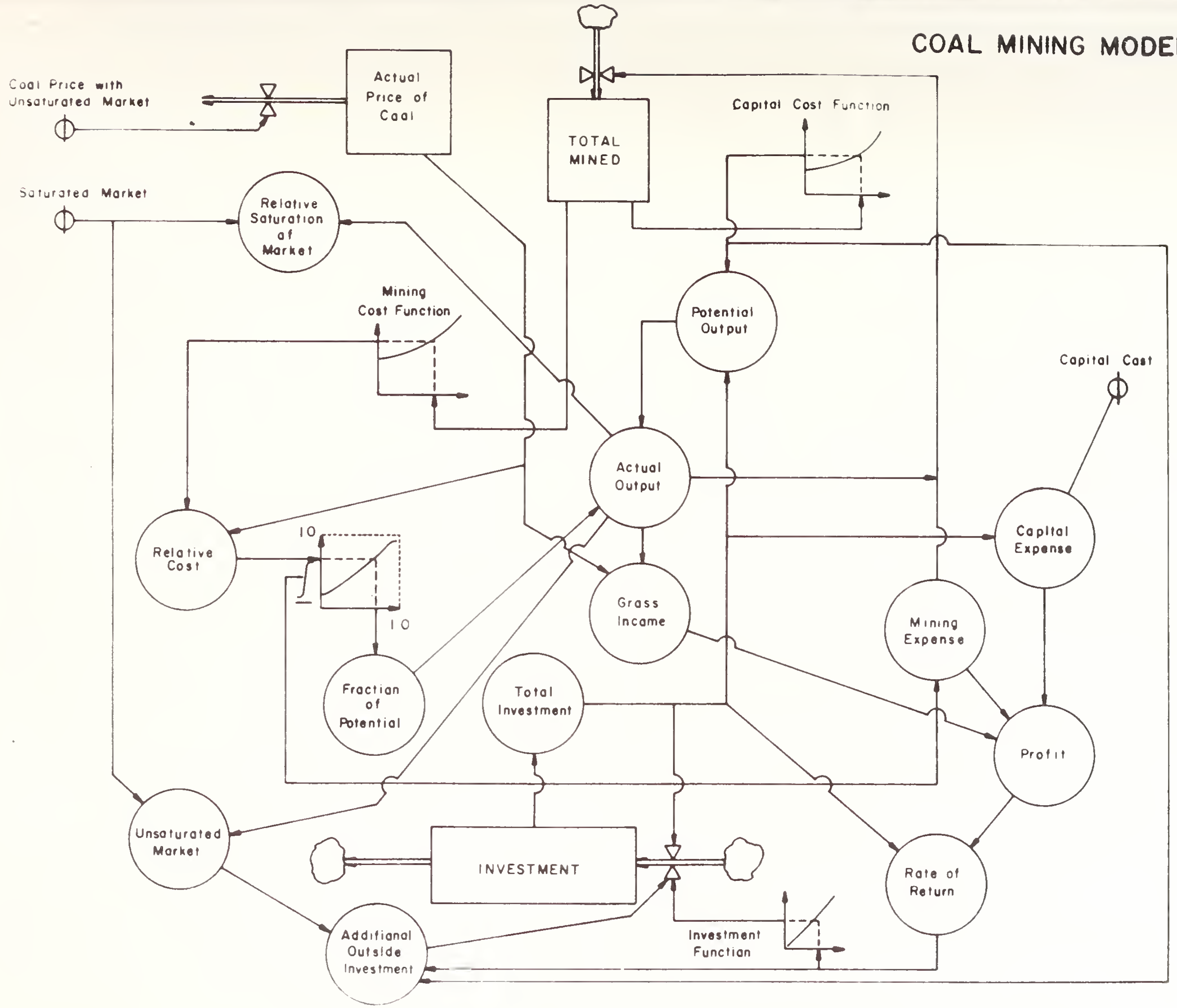


Figure 2

Oil and Gas Sector

The oil and gas sector consists of parallel, coupled models; one for oil discovery and production and one for gas discovery and production. The models are coupled since the production of oil normally has some gas production with it and the production of fields which are primarily for gas usually results in the production of some liquids. Similarly, when exploration for oil fields is carried out, there is some probability of finding a gas field or vice versa. The production part of the model is shown in Figure 1a and the exploration part in Figure 1c. The following discussion deals only with the production and exploration for oil since the structure is the same for gas.

When an oil or gas field is discovered, the income obtained from the field is spread over a long period of time, as are the expenses of developing and producing the field. The value of these cash flows must be discounted if the profit for discovering the field is to be accurately determined. This is shown in Figure 1b.

When oil is discovered it is placed in the producing level. Within this level, information is retained as to the age of each discovery. Four functions are required to describe the performance of producing reservoirs. Figure 2 shows the production function. This function traces the rate of production from a typical reservoir starting with the discovery of the field, moving through the development of the field to a period of relatively steady-state production, and then on to a long period of steady decline as the reservoir is depleted. These production rates are all based on the amount of initial recoverable oil in place. Therefore, if the total amount of oil for fields of each age is multiplied by the production rate for that age and summed for

fields for all ages, the total production rate at any point in time can be calculated.

Figure 3 shows the operating expense function. This function shows the operating expenditures required to operate a producing field of a given age. This function is also based on the initial recoverable oil in place. The total operating expense for oil production can be determined by multiplying the amount of oil for fields of each age by the rate at which expenditures are required for that age.

Figure 4 shows the investment function. This function gives the rate at which investment must be made in order to develop and maintain a field. In the early years of the field's production, the investment rate is quite high since the field is under development. In later years the rate drops to a low level since little additional equipment, etc. are required. The operating expense function and the investment function combine to give the total expense for production. As before, the total rate of investment is determined by multiplying the investment rate for each age by the amount of oil for that age.

Figure 5 shows the variable cost of production. It is similar to the operating expense function except that it describes the cost on the basis of unit of production for fields of each age. This function is used to compare the price to the variable cost. Normally, as a reservoir is depleted the costs per unit of production increase. Thus, the price will determine how long fields are produced before being abandoned. A cut-off age is determined where the price equals the cost. Fields older than this are removed from production.

The total oil production is the sum of the oil produced in oil fields plus the liquids produced in natural gas fields. Similarly, with the oil production, a certain amount of gas is produced determined by the average gas/oil ratio.

The total income for oil production is then the oil produced in oil fields multiplied by the oil price plus the gas produced in the oil fields multiplied by the wellhead gas price. The expenses for the production come from the total operating expenses plus the costs for capital. Capital is assumed to be amortized at a specified interest rate, over a 20 year time span. The net profit rate per barrel of oil is determined by subtracting the expenses from the income and dividing by the production rate.

The rest of the model deals with exploration. Two additional functions are required here. Figure 6 shows the depletion function. This function gives the increase in drilling required for additional discoveries as more and more of the oil is discovered. Figure 7 shows the investment function. This function gives the rate of investment in terms of the profit rate. It is similar to the same function for other industries.

From the depletion function, the oil discovered per foot of drilling is determined. From the investment in exploration drilling, the drilling cost, and the drilling investment life, the rate of drilling is determined. These combine to give the direct discovery rate of oil. The oil discovered in gas exploration is added to determine the total discovery rate for oil. The income for oil exploration is determined by multiplying the direct discovery rate for oil by the oil production profit and adding the gas discovered in oil exploration multiplied by the gas production profit. The expense for the exploration is simply the cost for the investment amortized over the investment life. The income and expense are compared to determine the profit rate. This is used with the investment function to determine the investment rate.

The following list summarizes the inputs, parameters, and key outputs for the oil and gas model. Figures 2-6 show functions required for the oil part of the model. Similar functions are required for the gas part.

List of Inputs, Parameters, and Key Outputs for Oil and Gas Production and Exploration

---

Inputs:

Price of oil at wellhead ($/bbl)

Price of gas at wellhead ($/ft^3)

Parameters:

Average producing gas/oil ratio for oil fields (ft^3/bbl)

Average producing oil/gas ratio for gas fields (bbl/ft^3)

Capital cost for production investment ($/$capital/Yr)

Gas fields discovered in oil exploration (ft^3/bbl)

Oil fields discovered in gas exploration (bbl/ft^3)

Exploration drilling cost ($/ft)

Exploration capital life (Yr)

Exploration capital cost ($/$capital/Yr)

Key Outputs:

Total oil production

Total gas production

OIL & GAS MODEL a) Production

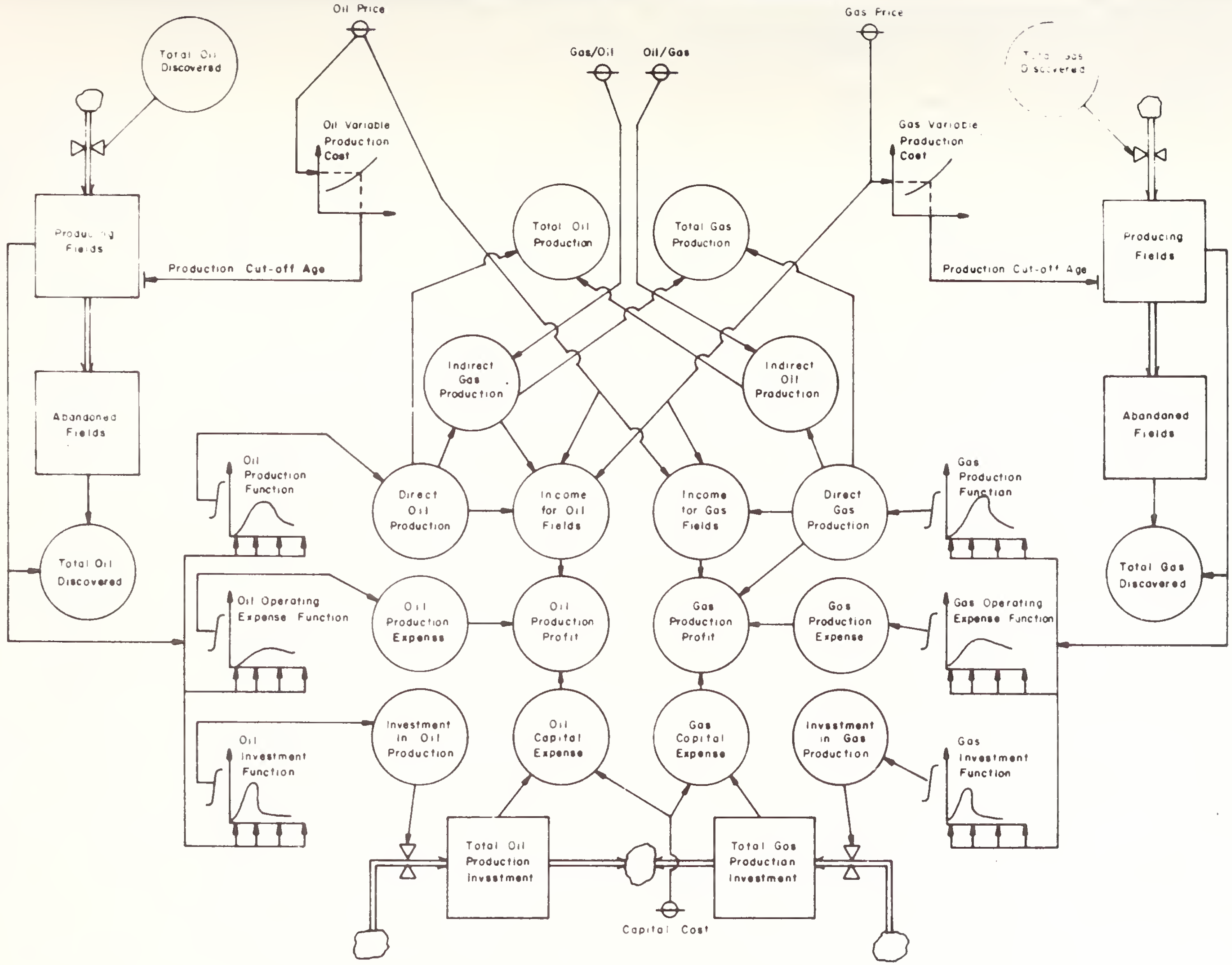


Figure 1a

OIL & GAS MODEL

b) Profit for Discoveries

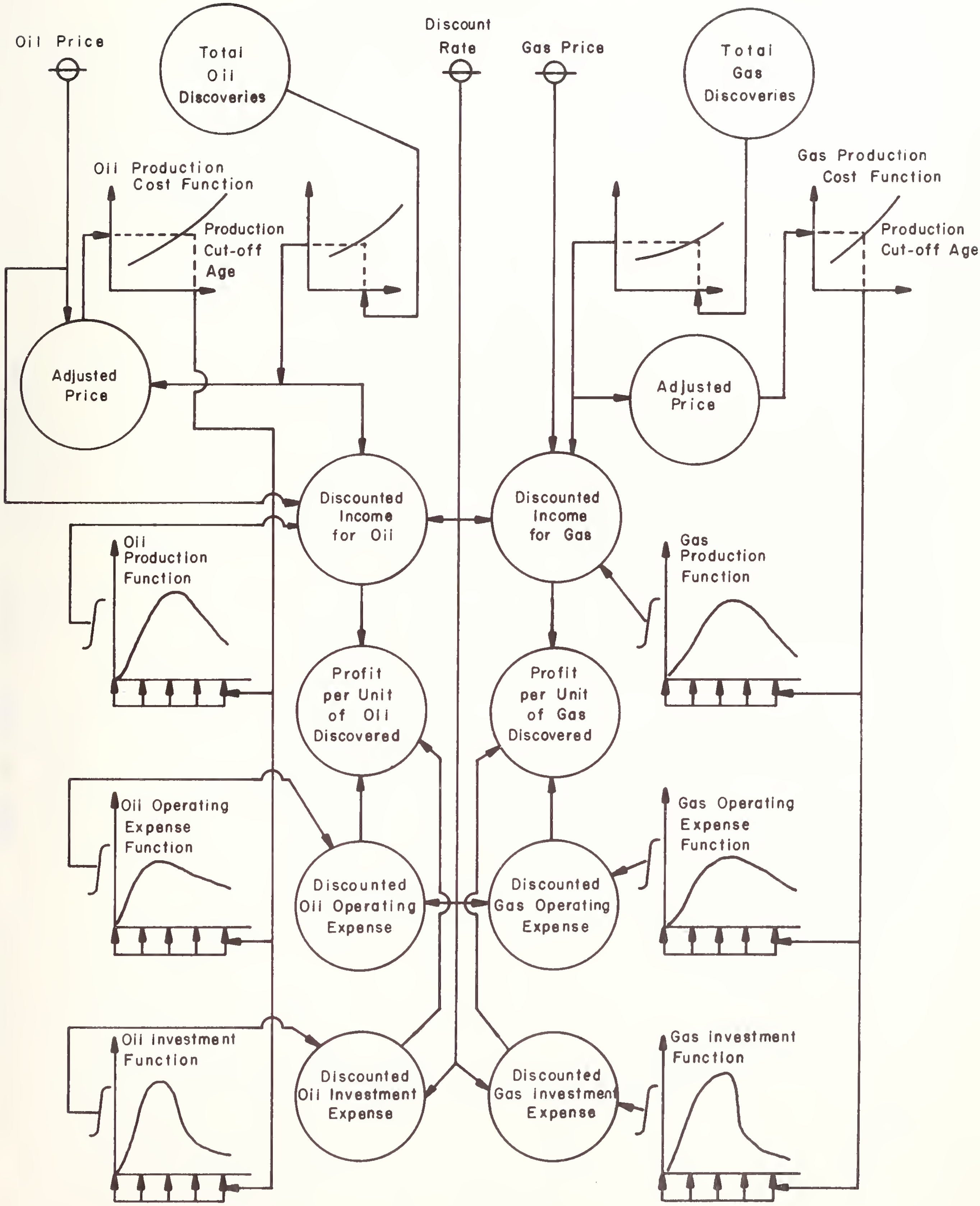


Figure 1b

OIL & GAS MODEL c) Exploration

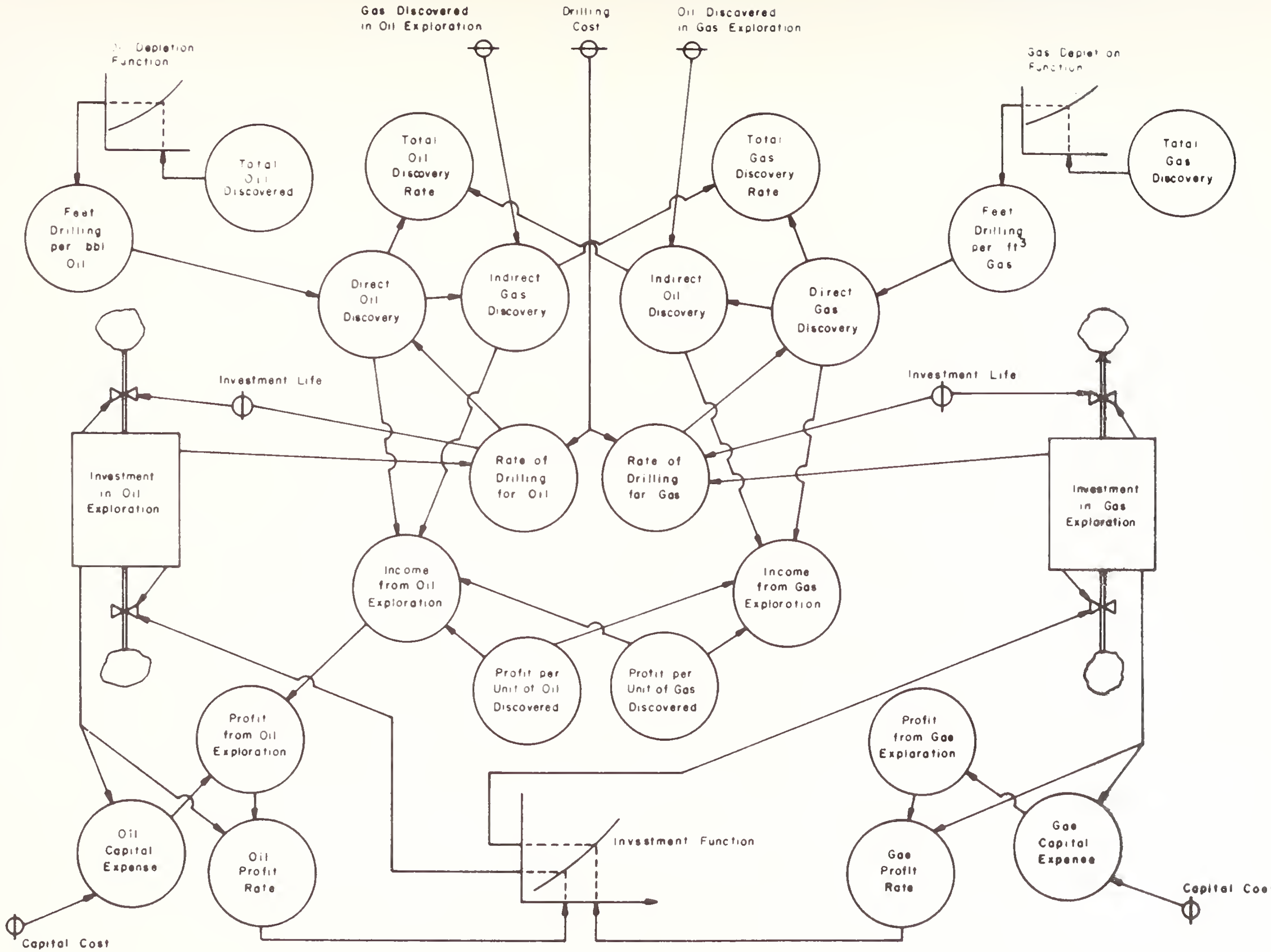


Figure 1c

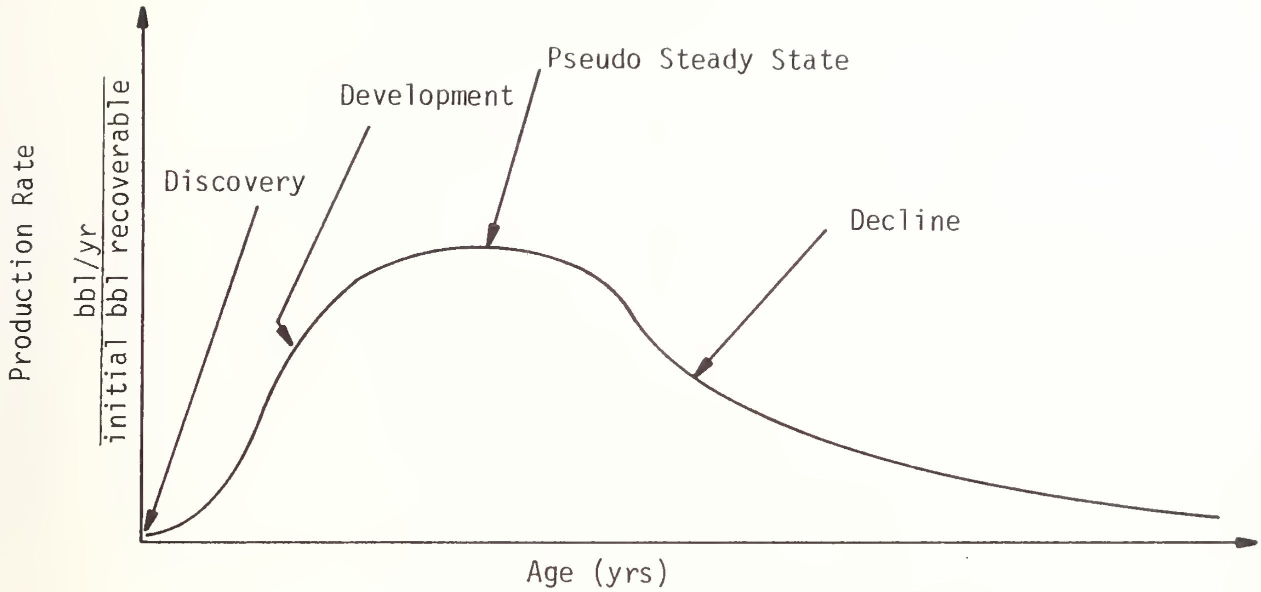


Figure 2.--Oil Production Function

Figure 3.--Operating Expense Function

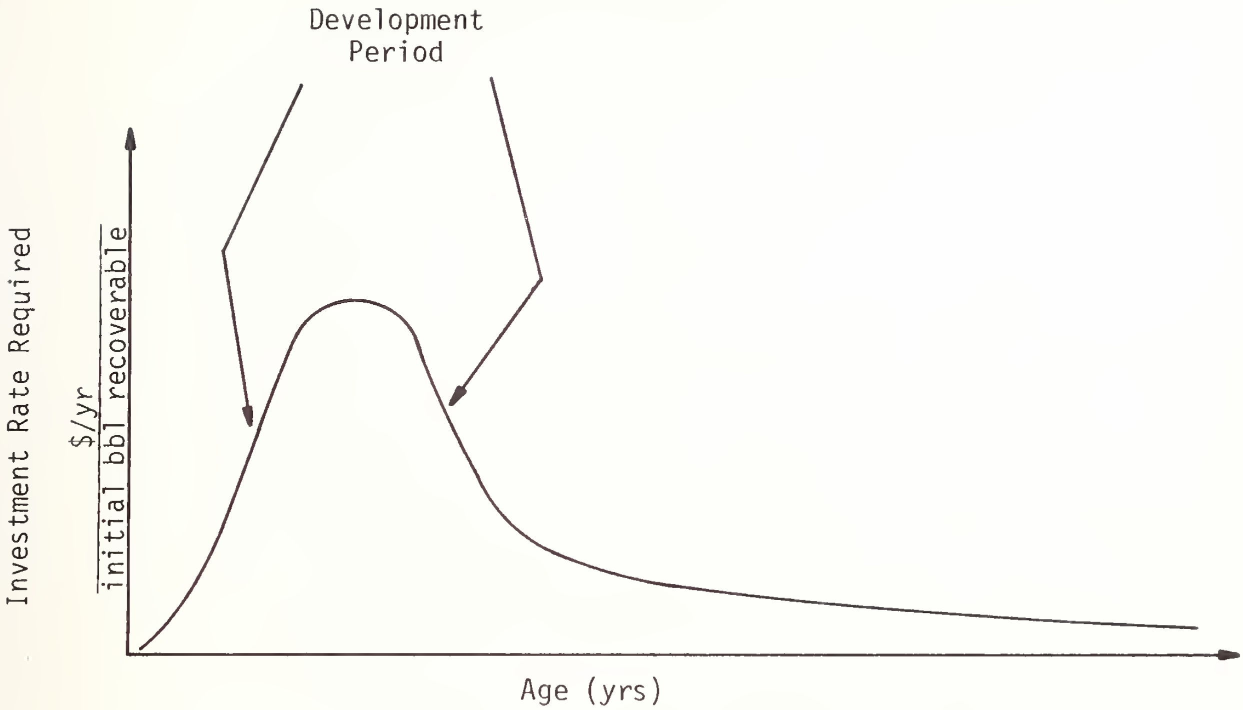


Figure 4.--Investment Function

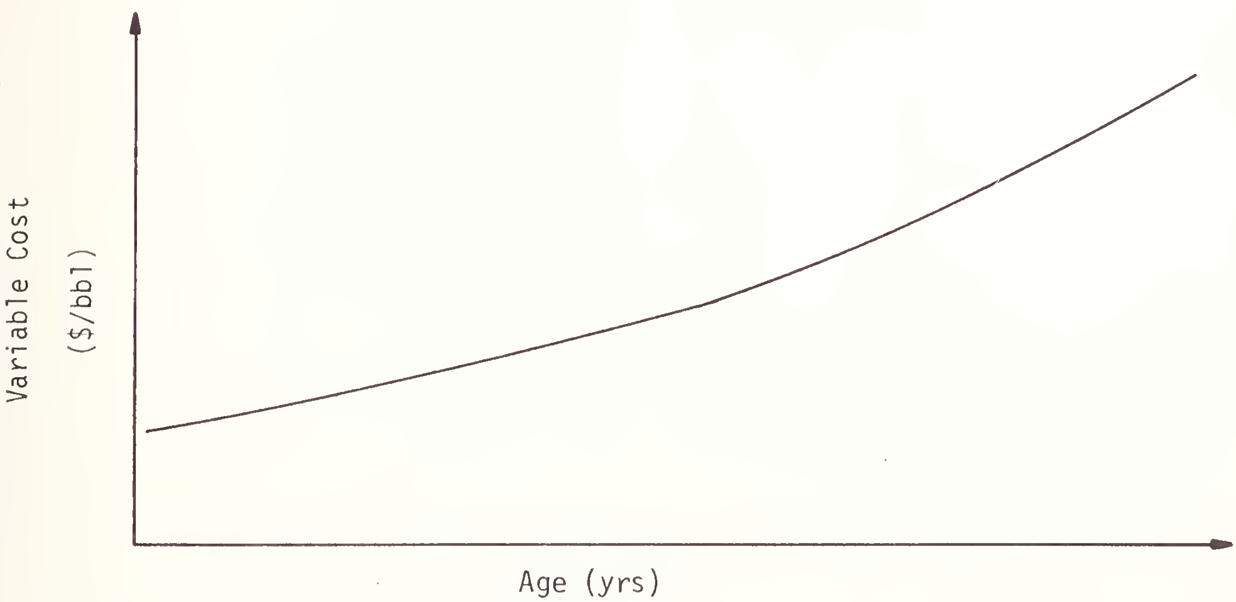


Figure 5.--Variable Cost of Production

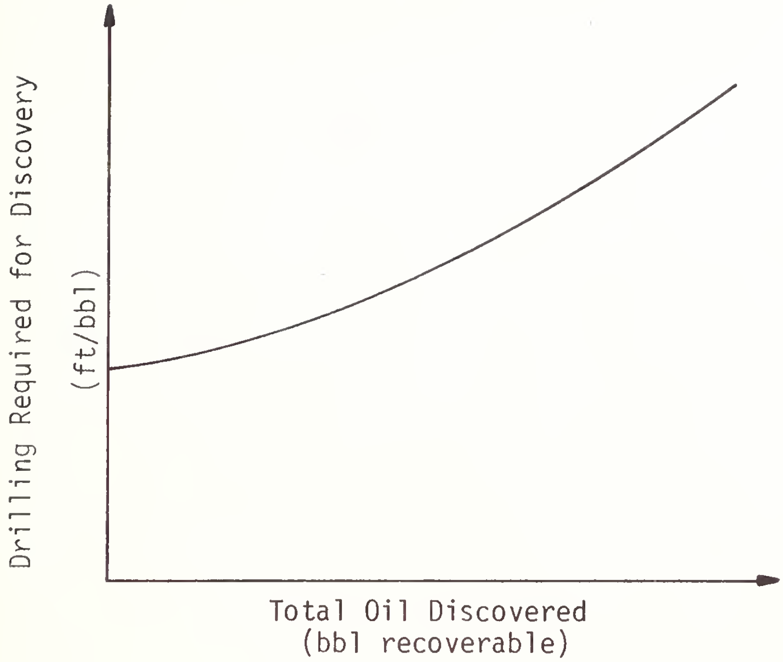


Figure 6.--Depletion Function

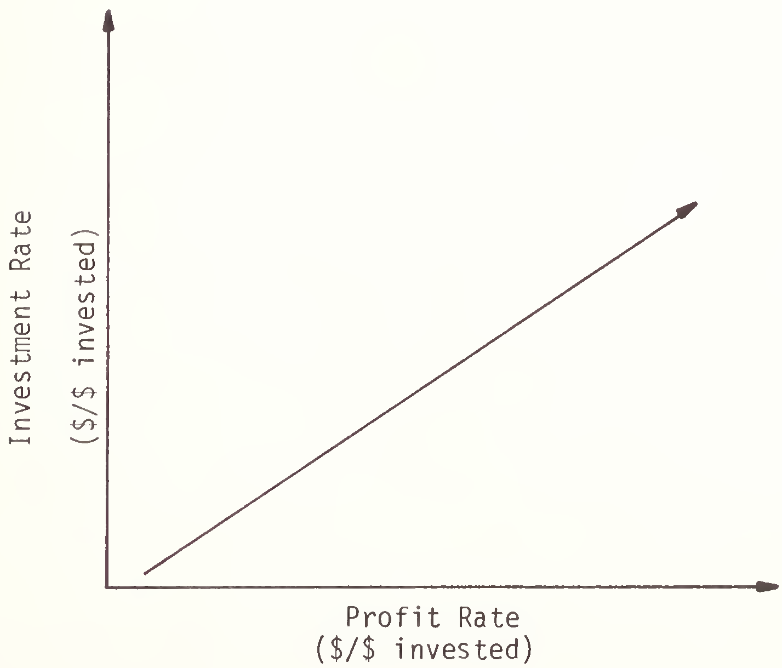


Figure 7.--Investment Function

Petroleum Refining Sector

The petroleum refining in Montana is related to the output of the petroleum production sector. It is also dependent upon imports of crude oil. These factors are more important than the actual demand for refinery products in Montana. Therefore, refining is considered separately rather than with oil production or oil demand in Montana.

The vast majority of the refinery capacity in Montana is located around the Billings area. However, the pipeline system is such that the oil produced in the eastern part of the state is not available to these refineries.(1) In 1975 Montana produced 32.8 x 10^6 barrels of crude oil, refined 48.1 x 10^6 barrels of oil, but refined only 8.9 x 10^6 barrels of oil which was produced in Montana.(2) In 1974 Montana produced 34.6 x 10^6 barrels. Of this, 10.2 x 10^6 barrels was from central Montana and thus available to Montana refineries; 24.4 x 10^6 barrels was produced in eastern Montana and was not available to the refineries.(1) By comparison, 9.3 x 10^6 barrels of Montana production were actually refined in Montana.(2)

Of the imports refined in 1975, 19.8 x 10^6 barrels came from Wyoming and 19.4 x 10^6 barrels came from Canada. It is difficult to predict the availability of these crude oil imports in the future, especially the Canadian imports. Since the companies who operate the pipelines and refineries are interstate in nature, it is difficult to predict whether or not they would reverse past practices and develop facilities to transport eastern Montana r oduction to Montana refineries if imports could not be obtained.

The model for petroleum refining assumes only central Montana production is available to the refineries. In addition, a scenario input of imports

available must be provided. It is assumed that additional capacity will not be added unless Montana production warrants it. This is an unlikely event. Thus, the maximum refinery output will depend upon the Montana production which is available plus the imports available or the maximum output of current capacity. Only if available Montana production should exceed the refinery capacity, will more capacity be installed. Since the oil and gas model gives oil production only in terms of the total for Montana, a parameter which states the fraction which is available to Montana refineries is required. Using 1974 data from Reference 1, the fraction of production from the central part of Montana is approximately 29%. From Reference 2, the total refinery capacity in 1975 was 161,000 bbl/day.

Primary Metals Sector

The output of the primary metals sector of the economy is dependent primarily upon the output of the metal mining sector. It is also very energy intensive. For the present, the primary metals output is assumed to be proportional to the non-energy mining output. Since it is a large energy user, it may be desirable to consider it in more detail later on. The ratio of the outputs from Reference 1 is:

$$\frac{\text{Primary Metals Output}}{\text{Non-Energy Mining Output}} = \frac{439.7}{177.0} = 2.48$$

References for the Economic Sub-Models

Agricultural Sector

1. Economic Component, Agricultural Sector, Oregon State Simulation Model, Willamette Simulation Unit, Oregon State University.

2. Entire paragraph was adapted from the agricultural sector of the Economic Component, Oregon State Simulation Model, Willamette Simulation Unit, Oregon State University.

3. Montana Data Book (Montana Department of Planning and Economic Development) Chapter 10 Agriculture.

4. U.S. Department of Commerce, Census of Agriculture-Montana, October 1971.

5. H. H. Fullerton, J. R. Prescott, An Economic Simulation Model for Regional Development Planning, Ann Arbor Science.

Forestry Sector

1. "Economic Component," Logging Sector: Willamette Simulation Unit, Oregon State University.

2. "Forest Industries," Montana Data Book, Chapter 9, Montana Department of Planning and Economic Development, State of Montana, 1970.

Coal Mining and Non-Energy Mining Sector

1. Montana University Coal Demand Study Team, Projections of Northern Great Plains Coal Mining and Energy Conversion Development 1975-2000, May 1976.

2. Montana Environmental Quality Council, Montana Energy Policy Study, February 1975.

3. Montana Energy Advisory Council, Montana Historical Energy Statistics, September 1976.

Oil and Gas Sector

1. "Annual Review for the Year 1974 Relating to Oil and Gas," Volume 18, Oil and Gas Conservation Division, Department of Natural Resources and Conservation, State of Montana.

2. Gustav Stolz, Jr., Oil and Gas Energy Resources of Montana, Montana Environmental Quality Council, 1974.

3. Maher Ibrahim, Undiscovered Natural Gas Resources of Montana, Montana Energy Advisory Council, 1976.

References for the Economic Sub-Models (cont'd)

Petroleum Refining Sector

1. "Annual Review for the Year 1974 Relating to Oil and Gas," Volume 18, Oil and Gas Conservation Division, Department of Natural Resources and Conservation, State of Montana.

2. "Historical Petroleum Statistics for Montana," Montana Energy Advisory Council, Office of the Lieutenant Governor.

Primary Metals Sector

1. Input/Output Model, Montana Futures Project, Division of Research and Information Systems, Department of Community Affairs.

Section A-V, Economic Input/Output Sub-Model

The economic model is an input/output model for Montana.[1] The outputs for agriculture, forestry, coal mining, oil and gas, non-energy mining, petroleum refining, and primary metals are all determined elsewhere. The direct input/output coefficients are used to determine the demands for other products due to these outputs. These demands are then treated as demands exogenous to the input/output model. Additional exogenous demands arise from consumer spending, exports, and government spending. Each of these will be discussed separately.

Consumer Spending

Total consumer spending is assumed to be proportional to earned income. In effect, the elasticity is assumed to be unity. The consumer spending is assumed to be divided among the sectors of the economy as in the input/output model.

The total non-agricultural earnings (in 1972 dollars) was 2,036 million dollars in 1970 and 2,392 million dollars in 1974, for an average of 2,214 million dollars.[2] It is more difficult to estimate earned income in the agricultural sector. An estimate of approximately 350-360 million dollars in 1972 was made. This gives an initial estimate of 2,570 million dollars of earned income in 1972. The consumer spending in 1972 was 1,629 million dollars.[1] This gives a spending/earning ratio of 0.63.

Exports

It is not necessary to consider exports for the sectors considered as exogenous to the input/output model. Of the endogenous sectors, only meat processing, railroads, communications, utilities, and retail trade have significant exports. The railroad sector is the only one for which exports

dominates. For the others a constant ratio between consumer demand and export demand is assumed.

In 1972 $\$104 \times 10^6$ out of a total railroad output of $\$179 \times 10^6$ was exported. It is difficult to predict how this export demand may increase in the future. If there is a large development in the coal industry (which is quite likely) it would directly affect the export demand for rail transportation. The current cost of coal transport by rail is approximately 1¢/ton-mile. If exported coal travels an average of 100 miles in Montana, there is approximately $1/ton rail export which results.

The exports demand for rail transportation is currently calculated in the model by the following equation.

Rail Export Demand = $\$100 \times 10^6$/yr + $1/ton x Coal Output

Government Spending

Government spending for both federal and state and local governments is assumed to be proportional to earned income. Federal spending in 1972 was 1,092 million dollars.(1) Using the previous estimate for earned income, the respective spending/earnings ratios are 0.42 and 0.25 (federal, state, and local).

Economic Input/Output Sub-Model References

1. Input/Output Model, Montana Futures Project, Research and Information Systems Division, Department of Community Affairs, State of Montana.

2. M. C. Johnson, "Montana's Economy: Where It's Been and Where It's Going, "Montana Business Quarterly, Vol. 14, No. 1, Winter 1976.

Section A-VI, Capital Investment Sub-Model

The structure of the capital investment model for a single sector is shown in Figure 1. The same structure is used for all non-primary sectors. The capital investment for the primary sectors is determined in their individual models.

The capital investment model uses exponential delays to average both the output and the rate of change for a sector. The averaged rate of change is added to the depreciation rate to get the total investment rate required. However, if this rate is negative, there is no negative investment. If it is positive, it is multiplied by the averaged output and the capital output ratios and depreciation rates are taken from Reference 1. They are listed in Table 1. An "averaging delay time" of 5 years is used.

Table 1. Capital-Output Ratios and Depreciation Rates

Sector	Capital-Output Ratio	Depreciation Rate
Construction	0.19	0.093
Food and Kindred Products	0.25	0.065
Printing and Publishing	0.39	0.066
Chemicals and Allied Products	0.50	0.067
Other Manufacturing	0.59	0.082
Transportation	1.76	0.038
Communications and Utilities	3.00	0.033
Trade	0.65	0.052
Finance, Insurance, Real Estate	1.05	0.047
Services	0.95	0.097
Government	0.95	0.097

CAPITAL INVESTMENT FOR A SINGLE SECTOR

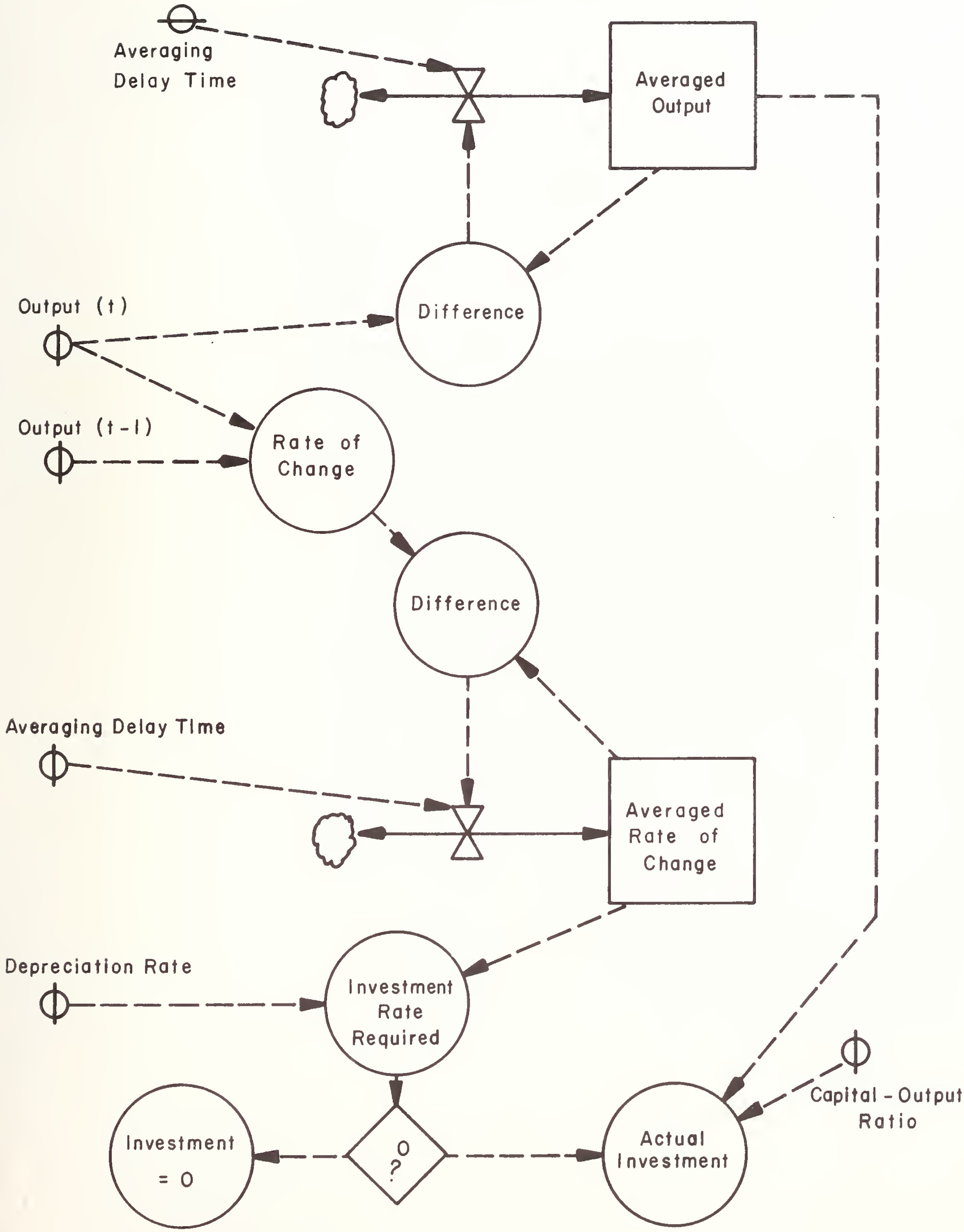


Figure 1

Capital Investment Sub-Model References

1. H. H. Fullerton and J. R. Prescott, An Economic Simulation Model for Regional Planning, Ann Arbor Science Publishers Inc., Ann Arbor, Michigan 1975.

Section A-VII, Employment Sub-Model

The structure of the employment model is shown in Figure 1. Employment is divided into three groups along the same lines as in Reference 1. These groups and the sectors included are:

1. Agriculture -
2. Non-Agricultural Primary-

    Mining
    Manufacturing
    Railroads
    Federal Government

3. Derivative -

    Utilities
    Construction
    Trade
    Services and Finance
    State and Local Government
    Other

This division is made to account for the fact that wage rates for the different groups vary considerably.

The employment levels are determined by projections of the employee/output ratios.(2) These are presented in Table 1. A linear interpolation is made for years between those given. After 1985 they are assumed to stay constant. Employee/output ratios are not given for agriculture or government.

Government employment should relate to government spending in much the same way as private employment relates to output. In 1970 the federal government provided 11,900 jobs and in 1974, 13,000 jobs.(1) From reference 3, the federal government spent $\$1.092 \times 10^9$ in 1972. Using the average employment gives an employee/spending ratio of 11.4 employees/million dollars.

In 1970 the state and local governments provided 40,700 jobs and in 1974 they provided 45,200 jobs.(1) In 1972 state and local governments

spent $655 x 10^6.[3] Using the same method as above, the employee/spending ratio for state and local governments obtained is 65.6.

As can be seen in Table 1 the employee/output ratios are expected to decline in the private sector. Similar declines can probably be expected for government employment. The above coefficients are arbitrarily assumed to decline by 20% in 1980, by 26% in 1985, and stay constant thereafter. This is somewhat less decline than most of the ratios for the private sector.

The employment in the agriculture sector is treated similarly. The total agriculture output in 1972 was $875.3 x 10^6.[3] The agriculture employment was 36,100 in 1970 and 35,100 in 1974.[1] Using the same method as before, the employee/output ratio for agriculture obtained is 40.7. There have been large decreases in the agriculture employee/output ratio in the past. However, it is assumed that the decreases will be more moderate in the future. The ratio is arbitrarily assumed to decrease by 25% in 1985, by 35% in 1980, and to hold constant thereafter.

The employment for the various sectors are summed to determine the total employment. The total work force available is determined by multiplying the total population as supplied by the demographic model by the employee/population projection shown in Table 2. These ratios are obtained by altering employment population ratios from Reference 2 to account for the unemployment considered in these ratios. The total employment and the total work force are compared to determine the unemployment rate.

The wage rates for the non-agricultural primary and the derivative groups increase in real terms if unemployment drops below 5%. When unemployment is higher than this the wage rates are assumed to stay constant. The wage rates for the agriculture sector are somewhat different since a

large part of the employment consists of farm operators. For them, the wage rate depends upon the net farm receipts which are not reinvested. For hired hands, the wages are assumed to change in the same manner as for the other groups. The fraction of employees which are hired must be supplied as a parameter. From Reference 4 the average number of hired farm workers was 11,000 in 1969. Compared to the total employment of 36,100 in 1970 this gives a fraction of about 30%. This fraction is assumed to state constant.

In order to start the simulation, it is necessary to have initial values for the wage rates. The wage rate for derivative workers was $5,072/yr. in 1974;[1] for non-agricultural primary workers it was $9,480/yr in 1974 [1] (both in terms of 1967 dollars). The wage rate for hired farm labor was $3,340 in 1969 as determined for the agriculture model.

Table 1. Employee/Output Ratios*

Employee /$\$10^6$ Output			
1972	1980	1985	Sector
25	18	16	Non-fuel Mining
11	9	7	Coal
14	13	12	Crude Petroleum
33	24	20	Construction
16	13	11	Food Processing
30	21	17	Lumber and Products
5	4	4	Petroleum Refining
9	7	6	Primary Metals
28	23	21	Other Manufacturing
37	22	17	Railroad
38	33	14	Motor Freight
32	21	17	Communication
14	10	8	Utilities
78	64	58	Trade
17	14	13	Finance, Insurance, Real Estate
118	100	92	Service

* All in 1972 dollars.

Table 2. Projection of Work Force/Population Ratio

Year	Work Force/ Population
1975	0.48
1980	0.51
1985	0.515
1990	0.52

EMPLOYMENT MODEL

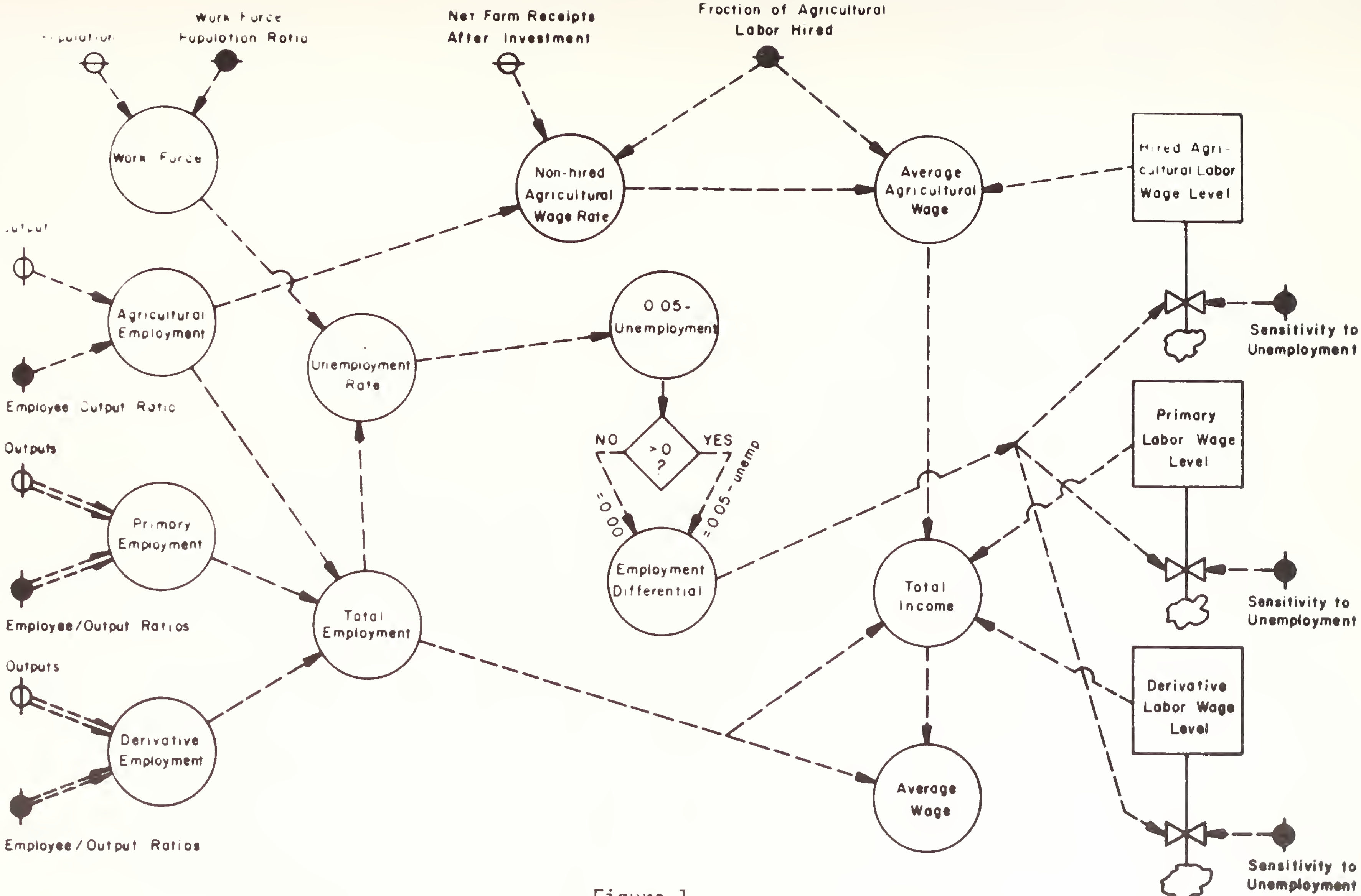


Figure 1

Employment Sub-Model References

1. M. C. Johnson, "Montana's Economy": Where It's Been and Where It's Going", Montana Business Quarterly, Vol. 14, No. 1, Winter 1976.

2. Montana Futures Project, Division of Research and Information Systems, Department of Community Affairs, State of Montana.

3. Input/Output Model - Reference 2.

4. "Agriculture," Montana Data Book, Chapter 10, Department of Planning and Economic Development, State of Montana 1970.

Section A-VIII, Energy Sub-Model

The energy sub-model is divided into demand and supply sections. The demand section is fairly detailed while the supply section is fairly simple and obtains a large part of its information directly from the economic sub-model. Each section will be discussed separately.

Energy Demand

The demand for energy is analyzed along the traditional lines of residential, commercial, and industrial usage. Each part of the demand is treated somewhat differently and is discussed separately. Agricultural energy demand is considered separately also.

Residential Demand

The demand for residential energy is divided among its various end uses. These are:

Space Heating
Water Heating
Kitchen Ranges
Refrigeration
Clothes Drying
Air Conditioning
Other

The actual residential demand for a particular form of energy for a particular end use is determined by the following relationship:

$$E_{i,j}=A_{i,j} \times S_{i,j} \times TH$$

where

$E_{i,j}$ is the consumption of energy type i by end use j.

$A_{i,j}$ is the average consumption of energy for this type of end use in a typical household.

$S_{i,j}$ is the saturation of type j end use using energy type i, and

TH is the total number of households.

Current average uses and saturations form a baseline rate of energy use. Energy use can change from this baseline in three ways:

1. Change in average energy consumption for an end use,
2. Change in the relative saturations of an end use between fuels, and
3. Change in the total saturation of an end use.

There are several factors which must be considered in determining these changes:

1. Price effect on energy consumption/end use,
2. Price effect on substituting one type of energy for another.
3. Price effect on total saturation of an end use,
4. Income effect on energy consumption/end use,
5. Income effect on total saturation of an end use, and
6. Trends from a "market entry effect".

Current investigation has focused on determining the baseline coefficients. The derivation of these follows.

Yearly energy consumption data for the electric end uses were taken from reference 1. This was used unaltered except for air conditioning and heating. Heating consumption was determined by multiplying the average consumption in Los Angeles by the ratio of Montana to Los Angeles heating degree days obtained from reference 2. Due to the relatively cool climate in Montana, energy consumption by air conditioners was assumed to be one-third of a typical California window unit.

To determine the annual energy consumption for non-electric end uses, the energy consumption by similar electric end use was multiplied by the ratio of electric efficiency divided by the efficiency for using the other energy source. These efficiencies were obtained from reference 3.

The saturation of each type of end use for each fuel was assumed to be the same as those reported in reference 4. The total number of households in Montana was assumed to be 7% greater in 1974 than reported in reference 5 in 1970. This is approximately equal to the total population growth in Montana during the same period as reported in reference 6. The total energy consumed in 1974 was then estimated by multiplying the energy per end use by saturation and then by the total number of households. The results were compared with the 1974 data for total residential electricity and natural gas consumption in references 7 and 8. Reference 7 was assumed to be more accurate. An "other" category was added for electricity to account for the large number of small end uses not considered initially. This was assumed to be the difference between the total predicted in the initial estimate and the total reported in reference 7 less the allowance for agriculture in reference 9. There are very few residential uses for natural gas not considered in the initial estimate. Therefore, the energy consumption for each end use was scaled to make the total agree with reference 7. Coal and oil were left the same as in the initial estimate. End uses of bottled gas were assumed to be the same as for natural gas.

Table 1.--Residential Energy/End Use and Saturation

Use	Electricity KWH/yr	Natural Gas 10^3Btu/yr	Oil 10^3Btu/yr	Coal 10^3Btu/yr	Bottled Gas & Other 10^3Btu/yr
Space Heating	27,500 2.3%	118,700 83.8%	141,300 7.1%	161,900 1.9%	118,700 4.9%
Water Heating	4,200 17.9%	20,700 78.7%	26,500 0%	88,300 0%	20,700 2.9%
Kitchen Range	1,180 78.2%	8,130 19.3%			8,130 2.3%
Refrigerator	1,140 105.1%				
Freezer	1,200 65.3%				
Clothes Dryer	990 68.8%	4,110 3.9%			4,110 0.3%
Air Conditioner	460 13.4%				

Table 2.--Average Residential Energy per Household by End Use*

Use	Electricity KWH	Natural Gas 10^3Btu	Oil 10^3Btu	Coal 10^3Btu	Bottled Gas & Other 10^3Btu
Space Heating	63	99,500	10,000	3,080	5,820
Water Heating	760	16,300			600
Kitchen Range	920	1,570			190
Refrigerator	1,200				
Freezer	780				
Clothes Dryer	680	160			12
Air Conditioner	62				
Total per Household	5,030	117,500	10,000	3,080	6,620
Total Montana**	$1,170 \times 10^6$	$2,300 \times 10^6$	$2,300 \times 10^6$	720×10^6	$1,540 \times 10^6$

* (Energy per End Use) x saturation
** Assumes 232,500 households

Table 3.--Comparison of Initial Estimate With Other Sources of Data

Total 1974 Montana Use
10^9Btu

Use	Electricity	Natural Gas	Oil	Coal	Bottled Gas & Other
Initial Estimate	4,050	27,300	2,300	720	1,540
Montana Energy Advisory Council (Reference 37)	6,400	21,600	---	---	---
Los Alamos (Reference 38)	6,500	23,600	4,000	200	---

Electricity unaccounted for put into "other" category:

Other Electricity=

$$\frac{(6{,}400 - 4{,}050) \times 10^9 \text{Btu}}{232{,}500 \text{ Households} \times 3{,}412 \text{ Btu/KWH}}$$

=2,960 KWH/Household x 0.25 (Adjustment for Agriculture)
= 740 KWH/Household

$$\frac{\text{Total Gas Use Reference } 7}{\text{Total Gas Use Initial Estimate}} = \frac{21{,}600}{27{,}300} = 0.79$$

Table 4.--Baseline Estimate - Energy per End Use

Residential

Use	Electricity KWH/yr	Natural Gas 10^3Btu/yr	Oil 10^3Btu/yr	Coal 10^3Btu/yr	Bottled Gas & Other 10^3Btu/yr
Space Heating	27,400	93,800	141,300	161,900	93,800
Water Heating	4,220	16,300	26,500	88,300	16,300
Kitchen Range	1,180	6,420			6,420
Refrigerator	1,140				
Freezer	1,200				
Clothes Dryer	990	3,250			3,250
Air Conditioner	460				
Other	740*				

* Energy not accounted for per household by above end uses less the agriculture allowance. A 100% saturation should be used.

Residential Demand References

1. C. C. Mow, W. E. Mooz, S. K. Anderson, "A Methodology for Projecting the Electrical Energy Demand of the Residential sector in California," R-995-NSF/CSRA, Rand Corporation, March 1973.

2. "Future Gas Consumption of the United States," Vol. 6, The University of Denver Research Institute, December 1975.

3. Stanford Research Institute, "Patterns of Energy Consumption in the United States," Office of Science and Technology, Executive Office of the President, January 1972.

4. "Residential Appliance Saturation Survey," The Montana Power Company, January 1974.

5. "General Housing Characteristics," 1970 Census of Housing, advance report, U.S. Department of Commerce/Bureau of the Census, September 1970.

6. M. C. Johnson, "Montana's Economy: Where It's Been and Where It's Going," Montana Business Quarterly, Vol. 14, No. 1, Winter 1976.

7. Energy use summary prepared by the Montana Energy Advisory Council, preliminary version, 1974 data used in calculations.

8. A. J. Barret, W. A. Beyer, and C. D. Kolsted, "Rocky Mountain Energy 1974: Flow, Employment, Prices," LA-6122-MS, Internal Report, Los Alamos Scientific Laboratory, October 1975.

9. See section on agriculture energy usage.

Industrial Demand

Industrial energy demand is determined separately for each sector. The use of a particular type of energy in a given sector is determined by the following relationship.

$$E_{i,j} = A_{i,j} * O_j$$

where:

$E_{i,j}$ is the use of energy type $_i$ in sector $_j$,

$A_{i,j}$ is the energy type $_i$ consumption per unit of output, and

O_j is the output of sector $_j$.

Where possible it was desired to have the energy use coefficient in terms of physical measures of output rather than dollars of output. However, in most cases this was impossible due to multiple product from a single sector or lack of data.

For most sectors, energy use and output were determined from separate sources and compared to evaluate the coefficients. In a few cases energy use per unit of output could be determined by other methods. Table 5-8 show the data used in calculating the coefficients and the coefficients calculated. In some cases the energy use is for a different year than the output. This is undesirable, but is necessary until more data are available. Wherever possible the energy use and output were taken for years as close together as data allowed.

The coefficients are complete for gas and electricity. However, for coal and petroleum the data are poor. Fortunately, this will not affect this study significantly as most petroleum and SNG will see different markets. With coal, the main concern is with the converting of existing natural gas uses to coal.

Table 5. Industrial Use of Electricity

Sector	Energy Use (MWH/Yr)	Output (10^6 \$/Yr)	Energy Coefficient (MWH/10^6 \$)
Coal Mining	8,060[1]	105.0[2] (21.1 x 10^6 tons)[2]	76.8 (382 MWH/10 ton)
Metal Mining	306,679[1]	143.5[2] (100.7 x 10 tons of copper dominates)	2,137
Petroleum and Natural Gas	191,191[1]	253.4[2]	786
Non-Mineral Mining	54,095[1]	17.3[2]	3,127
Food and Kindred Products	69,577[3]	257.7[4]	270
Printing and Publishing	6,414[3]	32.3[4]	199
Chemical Products	489,802[3]	24.6[4]	19,911
Lumber and Wood Product, Paper and Allied Products	386,223[3]	299.0[4]	1,292
Petroleum Refining	311,767[3]	232.5[4]	1,335
Primary Metal	3,829,054[3]	439.7[4]	8,708
Fabricated Metals	580[3]	13.9[4]	41.7
Stone, Clay, Glass, and Concrete	81,704[3]	42.4[4]	1,927
Other Manufacturing	1,744[1]	255.0[2]	6.8
Agriculture	484,000[5]	576.0[6]	840
Utilities	----	----	----
Railroads	23,000[3]	178.7[4]	129
Motor Freight	0	----	----

Superscripts refer to references at the end of this section.

Table 6. Industrial Use of Natural Gas

Sector	Energy Use ($10^6 ft^3$/Yr)	Output (10^6 \$/Yr)	Energy Coefficient (ft^3/\$)
Total Mining	3,367[7]	519.2[2]	6.48
Food and Kindred Products	1,270[7]	257.7[4]	4.93
Printing and Publishing	508[7]	32.3[4]	15.7
Chemical Products	1,100[7]	24.6[4]	44.7
Lumber and Wood Products, Paper and Allied Products	5,600[7]	299.0[4]	18.73
Petroleum Refining	6,195[7]	233.5[4]	26.5
Primary Metal	13,100[7]	439.7[4]	29.8
Fabricated Metals	436[7]	13.9[4]	31.4
Stone, Clay, Glass, and Concrete	4,400[7]	42.4[4]	103.8
Other Manufacturing	1,536[3]	255.0[4]	6.02
Agriculture	0[5]*	----	0
Utilities	1,109[7]	212.5[4]	5.22
Railroads	0	----	----
Motor Freight	0	----	----

* See Agricultural Energy Demand section.

Table 7. Industrial Use of Petroleum

Sector	Energy Use (10^3 bbl/yr)	Output (10^6 \$/Yr)	Energy Coefficient (bbl/10^3 \$)
Railroad Transportation	1,840[8]	178.7[4]	10.30
Utilities	25[8]	212.5[4]	0.118
Agriculture	3,090[5]*	576.0[6]	5.36
All Other Industrial	2,288[8]	1,899.8[4]	1.20
Highway Use (Allowing for Ag Highway)	7,197[9]	----	----

* See Agricultural Energy Demand Section

Table 8. Industrial Use of Coal

Sector	Energy Use (10^3 tons/Yr)	Output (10^6 \$/Yr)	Energy Coefficient
Utilities	769[10]	229.9 [4]	3.34
Other Industrial	318[10]	2,213.8 [4]*	0.144

* Does not include agriculture

Industrial Demand References

1. Energy Use Summary prepared by the Montana Energy Advisory Council, preliminary version, (1975 data).

2. "Directory of Mining Enterprises for 1975," State of Montana Bureau of Mines and Geology, Bulletin 100, May 1976.

3. Reference 1 (1974 data).

4. Montana Futures Project Input Output Model, Research and Information Systems Division, Department of Community Affairs (1972 data).

5. See section on energy use in agriculture.

6. "1969 Census of Agriculture-County Data," U.S. Department of Commerce/ Bureau of the Census.

7. "Future Gas Consumption of the United States," Volume 6, The University of Denver Research Institute, December 1975. (1974 data)

8. Reference 1 (1972 data).

9. Reference 1 (1969 data).

10. L. H. Crump and C. L. Readling, "Fuel and Energy Data: United States by States and Regions, 1972," U.S. Bureau of Mines.

Commercial Demand

There appears to be very little data available which gives details on commercial energy demand. This is a common problem for all energy studies. Usually everything that is left over is lumped into the commercial category. According to reference 1, commercial energy use in the United States is approximated by the following proportions.

Heating and Air Conditioning	- 70%
Lighting	- 13%
Refrigeration	- 4%
Hot Water	- 3%
Other	- 10%

This gives no information concerning the use of various fuels, nor does it indicate what fraction of it is associated with various activities (wholesale trade, retail trade, professional services, etc.). It does indicate that heating and air conditioning dominate. In Montana, heating probably dominates.

Reference 2 gives the following uses of energy in Montana for the commercial sector:

Gas----------	19.5×10^{12} Btu
Oil----------	11.2×10^{12} Btu
Electricity--	4.7×10^{12} Btu
Coal---------	0
Total--------	35.4×10^{12} Btu

For comparison, 1974 data from reference 3 for commercial energy usage is shown below. These are all residuals after all other uses have been accounted for.

Natural Gas--	14.3×10^{12} Btu
Electricity--	6.2×10^{12} Btu
Coal---------	2.6×10^{12} Btu
Oil----------	10.3×10^{12} Btu
LPG----------	3.1×10^{12} Btu
Total--------	36.5×10^{12} Btu

The discrepancies are probably due largely to differences in definitions. The total for the two sets of data are within about 3% of each other. Since

reference 3 was used in the residential sector, it was used in the model to maintain consistency.

If the relative proportions for end uses given previously were true in Montana, the lighting and refrigeration categories would use 6.4 x 10^{12} Btu; more than the total electricity use above. Reference 4 gives a somewhat different end use breakdown for the commercial sector indicating the previous numbers are by no means certain:

Heating and Air Conditioning	60.4
Water Heating	7.5
Refrigeration	7.6
Cooking	1.6
Asphalt and Road Oils	11.2
Other	11.7

Using this breakdown as a rough guide the energy use in the commercial sector was divided as shown in Table 9. This table is arbitrary and should be treated as such. The numbers in Table 9 were then used to develop energy coefficients for the commercial sector. The output for the commercial sector was also treated as a residual. It consists of all trade, service, and government sectors; the construction sector; and the communications sector. From reference 5, the total output for these sectors is 1924 million dollars in 1972. From reference 6 it is seen that income in Montana increases approximately 5% from 1972 to 1974. It was assumed that commercial output increased similarly. An adjusted output of 2,021 million dollars was then calculated. Table 9 and this value for output were then used to calculate the energy coefficients shown in Table 10. Energy conversion factors were taken from reference 7.

Table 9. Estimates of 1974 Energy Use in the Commercial Sectors*

End Use \ Energy Use	Gas (10^{12} Btu)	Coal (10^{12} Btu)	Electricity (10^{12} Btu)	Oil (10^{12} Btu)	LPG (10^{12} Btu)
Space Heating	11.8	1.8	0.1	3.8	2.5
Water Heating	2.2	0	0.1	0.1	0.2
Refrigeration	0	0	2.6	0	0
Lighting	0	0	2.9	0	0
Asphalt and Road Oils	0.1	0	0	3.7	0.2
Other	0.2	0.8	0.5	2.7	0.2
Total	14.3	2.6	6.2	10.3	3.1

* These estimates are crude and should be used with caution.

Table 10. Baseline Commercial Energy Coefficients(Energy Use per Unit of Output)

End Use \ Energy Coefficient	Gas $ft^3/\$$ (Btu/$)	Coal lb/$ (Btu/$)	Electricity KWH/$ (Btu/$)	Oil gal/$ (Btu/$)	LPG gal/$ (Btu/$)
Space Heating	5.58 (5,582)	0.106 (851)	0.014 (47)	0.0129 (1,798)	0.0129 (1,183)
Water Heating	1.09 (1,041)	0	0.014 (47)	0.0003 (47)	0.0010 (95)
Refrigeration	0	0	0.360 (1,230)	0	0
Lighting	0	0	0.402 (1,372)	0	0
Asphalt and Road Oils	0.05 (47)	0	0	0.0126 (1,750)	0.0010 (95)
Other	0.95 (95)	0.047 (378)	0.069 (237)	0.0092 (1,277)	0.0010 (95)
Total	6.76 (6,764)	0.154 (1,230)	0.859 (2,932)	0.0351 (4,872)	0.0159 (1,466)

Commercial Demand References

1. "Residential and Commercial Energy Use Patterns 1970-1990," Federal Energy Administration Project Independence Blueprint Final Task Report, Volume 1, Federal Energy Administration, November 1974.

2. R. J. Barret, W. A. Beyer, and C. D. Kolstad, "Rocky Mountain Energy 1974: Flow Employment, Prices," LA-G122-MS, Informal Report, Los Alamos Scientific Laboratory, October 1975.

3. Energy Use Summary prepared by the Montana Energy Advisory Council, preliminary version.

4. Stanford Research Institute, "Patterns of Energy Consumption in the United States," Office of Science and Technology, Executive Office of the President, January 1972.

5. Montana Futures Project Input Output Model, Research and Information Systems Division, Department of Community Affairs, (1972 data).

6. M. C. Johnson "Montana's Economy: Where It's Been and Where It's Going," Montana Business Quarterly, Volume 14, No. 1, Winter 1976.

7. Henningson, Durham and Richardson, "Energy & Secondary Materials Market Report," Report for the Solid Waste Management and Resource Recovery Study, State of Montana, May 1976.

Agricultural Demand

There is little data reported for agricultural energy usage. It is very difficult to separate energy use for agriculture from that used for rural residential. An analysis for each fuel is made below.

Petroleum: Reference 1 reports that in 1969 $32.976 x 10^6 were spent on petroleum fuel and oil for agricultural production. If we assume that the average price was 25¢/gal in 1969 this indicates 3,090 x 10^3 bbl of petroleum was used in agriculture in 1969.

Electricity: No direct data for agricultural energy use was available. It is likely that most of it is reported in the residential category. When residential calculations were made, 2,960 KWH/yr/household were left unaccounted for. Some of this will be used in residential lighting and in small appliances, etc. However, a large part of it may represent agricultural usage.

First, consider what would happen if all of the residual was assumed to represent agricultural usage. From reference 2 there were 217,300 households in 1970. This gives 643 x 10^6 KWH/yr in the residual category. Reference 1 reports the agricultural output in 1969 as $576 x 10^6. Comparing these two gives:

1.12 KWH/$ Output

For comparison purposes, data were taken from reference 3 for California. Using these data the following results were obtained.

Agriculture Energy Use in California

Year	KWH/$ Output
1954	1.87
1959	1.83
1964	1.54

It is unclear whether or not rural residential use is included with this. It is likely that the values above are somewhat high. Also, agriculture in California is much different than in Montana. The more intensive farming practices in California would probably lead to higher energy usage. However, the above results do justify assuming that a significant part of the residual comes from agricultural usage. For initial purposes let us assume that all agricultural electricity is sold under residential classification and that it is 75% of the residual. This gives:

Electric Energy Use = 0.84 KWH/$ Output

Natural Gas: There is essentially no data available for agricultural use of natural gas. According to reference 4 a significant part of the total comes from gas siphoned off of pipelines crossing farms in exchange for right-of-way. This is not metered or paid for. It probably shows up in our totals as transmission losses. Due to the cost of installing distribution facilities, farm use is probably limited to larger users and shows up as "commercial." For the present we will assume no significant agricultural use of natural gas in Montana until more data are available.

Coal: There is no significant use of coal in agricultural production.

Bottled Gas: A significant fraction of total LPG is probably used in agriculture. However, at the present time no good data are available.

Agricultural Demand References

1. "1969 Census of Agriculture-County Data," U.S. Department of Commerce, Bureau of the Census.

2. "General Housing Characteristics-Montana," 1970 Census of Housing, Bureau of the Census.

3. W. E. Mooz and C. C. Mow, "A Methodology for Projecting the Electrical Energy Demand of the Commercial Sector in California." R-1106-NSF/CSRA, Rand Corporation, March 1973.

4. "National Energy Accounts: Energy Flows in the U.S. 1947, 1972," Volume I, JACKFAU-75-122-7, Jack Faucett Associates, Inc., July 1975.

Energy Supply

The energy supply part of the model is relatively simple compared to the energy demand. The actual supply modeling is done in the economic part of the model. It gives the total production of gas, oil, and coal. However, most of the coal production is destined for export and a significant part of the oil and gas production is not available for Montana use.

Energy Supply References

1. Montana University Coal Demand Study Team, Projections of Northern Great Plains Coal Mining and Energy Conversion Development 1975-2000, May 1976.

2. Montana Environmental Quality Council, Montana Energy Policy Study, February 1975.

3. Montana Energy Advisory Council, Montana Historical Energy Statistics, September 1976.

Section A-IX, Residential Energy Conservation Sub-Model

Space heating dominates other uses of residential energy in Montana. Most of this is done with natural gas. For these reasons, the investigation of conservation in the residential sector focused on space heating requirements.

Space heating requirements for a typical residence may be reduced by making investments in insulation and devices which reduce the heat loss or by changing the life style of occupants so that less energy is needed. The first option tends to be an economic decision and can be analyzed in a straightforward manner. The liklihood of changed life styles and the effect are more difficult to assess. The potential energy conservation from both investment and life style change was determined and a relatively simple dynamic model (which serves as a sub-model to the larger Montana model) was constructed to describe the process whereby the conservation takes place.

Energy Conservation With Insulation

The potential energy savings from insulating were determined by analyzing a "typical" house for various levels of insulation. The house used for the analysis is described in Figure 1 and Table 1. The insulation options investigated are listed in Table 2. These options represent a very wide range of possibilities and include most of the cases likely to be encountered in the near future.

Cost estimates to install the different forms of insulation for both new and existing houses were made. These estimates were based on published literature, local retail prices, and discussions with local dealers. The resulting estimates are shown in Table 3.

The energy savings realized by installing this insulation were determined using standard heat transfer calculations. These calculations are somewhat tedious and are presented separately in this section. The resulting decreases in heating requirements are shown in Table 4. The actual energy saving will be significantly greater than the Btu savings shown as they do not include the furnace efficiency.

Energy Conservation by Life Style Change

In addition to the savings from insulation, significant savings in space heating requirements can be achieved by actions taken by the occupants. Setting the thermostat back by 6° reduces energy use by 13% in a northern climate.[6] A 10° setback from 10 p.m. to 6 a.m. can result in a 12% savings.[6] Using standard heat load calculations shown later in this section, it was determined that closing off an unused room can save 6%.

These are typical of the savings which can be achieved with relatively simple measures. More drastic life style adjustments would be required for larger savings. It is difficult to predict to what extent these energy conserving measures will be employed. However, it is pretty certain that the less drastic measures would be taken if heating cost became a significant fraction of total income.

Residential Energy Conservation

The effects of conservation by insulating are simulated by dividing all housing into three categories:

Class A - No insulation

Class B - Marginal insulation consisting of 6" of ceiling insulation

Class C - Full insulation consisting of 12" of ceiling insulation, 4" of wall insulation 4" of floor insulation, storm windows, and storm doors.

The model keeps track of how many houses are in each class and based the space heating energy requirements on these numbers. The number of houses in each class may change by new houses being added, existing houses being abandoned and existing houses being upgraded. The structure of this model is shown in Figure 2.

New houses are divided among the three classes according to the economic gain expected from adding insulation when building. The return is calculated in the form of a payback period. A function, shown in Figure 3 is used to determine the fraction which will be in each class. This function is used to calculate the fraction which will be class C and the fraction which will be class A. The remainder are then class B.

Existing houses are upgraded according to the payback period for adding insulation. Again, a function is used to determine the rate at which insulation is upgraded. The function is shown in Figure 3. Class A houses may be upgraded to either class B or class C. Class B houses may be upgraded to class C. The rate at which upgrading takes place is determined for all cases by the same function.

The rate at which existing houses are abandoned is determined by the average life span of a house.

The actual energy for space heating for each class of house is then calculated. The structure of this part of the model is shown in Figure 4. The energy per household is calculated by modifying the "baseline" energy use, which corresponds to no insulation, by the savings which results from insulating. In addition, there is a savings from life study changes. These

are determined by the functions shown in Figure 5. Different functions are used for different classes of housing, since there is less to gain by taking these measures in houses which have high quality insulation and thus low energy requirements to begin with. Also, people with lower incomes will tend to be more affected by higher prices and they tend to have the houses with poorer insulation.

In order to use the conservation model, the number of housing units in each insulation class must be specified. No reliable data is available to determine these numbers. Strictly on the basis of judgment, the total number of households in Montana were divided as follows:

30% class A, 40% class B, 30% class C.

The main inputs tc the model are: the price of energy, the number of new households, and the "baseline" energy requirements of an uninsulated house. The price is a scenario input and the number of new households comes from other parts of the Montana model.

A calculation of heat losses from our "typical" home (if uninsulated) shows that it requires about 250 x 10^6 Btu/yr for space heating. If we assume a furnace efficiency of 55%, it would require about 450 x 10^6 Btu/yr of gas to heat this home in Montana. This is considerably higher than the gas demand for residential space heating used in the gas demand section of this report. This discrepancy could result from several causes. The size and structure of the "typical house" may not be typical. A significant number of households live in multiple family units which use less energy for space heating. Also, many people may supplement their gas heating system with wood or electricity. There is not enough data to

determine for sure how important these factors might be. To account for the discrepancies, the model is scaled to give space heating energy requirements consistent with the earlier estimates in this report (see section on residential gas demand).

Heat Transfer Calculations

The characteristics of the typical house are described in Figure 1 and Table 1. The thermal resistance for the walls, floors, and roof were calculated from data in the "ASHRAE GUIDE AND DATA BOOK." The component thermal resistances are shown below:

Wall		Roof		Floor	
Component	R-value	Component	R-value	Component	R-value
Outside Air	0.17	Outside Air	0.17	Outside Air	0.17
Siding	0.81	Shingles	0.43	Foundation*	5.26
Plywood	0.63	Plywood	0.61	Air Space	1.00
Air Space	1.17	Air Space	1.00	Plywood	0.78
Plaster Board	0.45	Plaster Board	0.45	Flooring	0.57
Inside Air	0.68	Inside Air	0.68	Inside Air	0.61
TOTAL	3.91	TOTAL	3.33	TOTAL	8.37

Windows were assumed to be single pane and undraped which gives an R-value of 0.88. The doors consisted of 1" of wood giving an R-value of 1.25.

The total heat transfer areas of each type of surface are divided by their respective R-values to determine their conductance.

Surface	Area	R-value	Conductance
Wall	680	3.9	174
Roof	1200	3.3	363
Floor	1200	8.4	143
Windows	300	0.88	341
Doors	63	1.25	50
		TOTAL. . . .	1072

* Foundation assumed to have little infiltration.

Thus the total conduction heat loss is approximately 1070 Btu/hr/degree of temperature difference.

In addition to the conduction losses, there are losses from infiltration. This was evaluated on the standard basis of 1 1/2 room air changes per hour. This corresponds to a room with doors or windows on two sides. The total heat loss is determined by:

$$Q = C_p \times \rho \times V \times A$$

where:

Q is the heat loss per unit of time per degree of temperature difference

C_p is the specific heat of air

ρ is the density of air

V is the volume of the house

A is the air change rate.

For our house we have

$$Q = 0.24 \text{ Btu/lb/F} \times 0.77 \text{ lb/ft}^3 \times 7 \text{ ft} \times 1200 \text{ ft}^3 \times 1.5\text{/hr}$$

$$= 233 \text{ Btu/hr/Degree Temperature Difference}$$

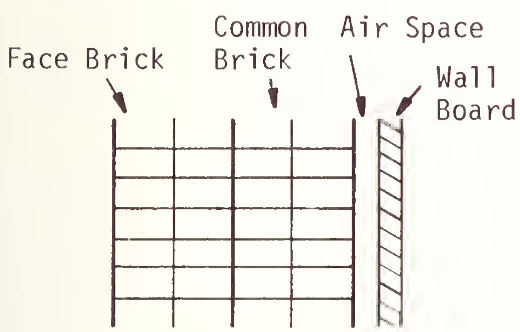
The total heat loss for the house is the combination of the infiltration and conduction losses or 1300 Btu/hr/Deg ΔT. This must be multiplied by 24 and by the number of heating degree days per year to determine the annual heating requirements.

This gives us our baseline estimate for a house with no insulation. To calculate the effect of insulation, its R-value is added to the existing R-value of the surface. Typical insulation has an R-value of 3.7 per inch of thickness. Also, the addition of storm windows and doors must be considered. The extra pane of glass increases the window R-value to 1.82. The storm door increases the total door R-value to 2.25.

The storm windows decrease the total infiltration by 1/3 and the storm doors by 10%. The following table summarizes the changes in the overall heat loss for each insulation option in Table 2.

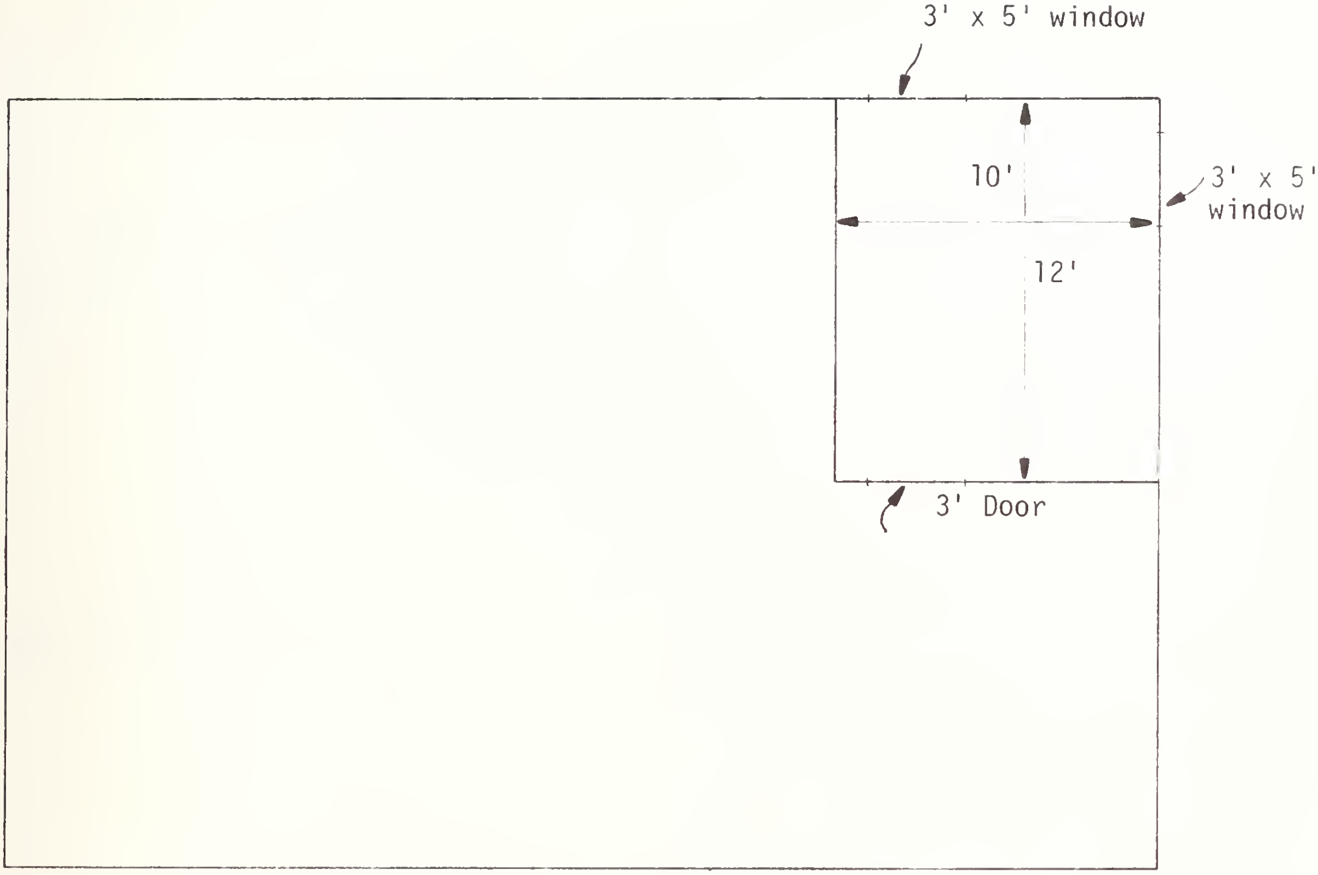
	Conduction				Infiltration		Total Heat Loss
	Wall	Roof	Floor	Windows	Doors	Windows	
None	174	364	143	341	50	233	1300
3" ceiling	174	83	143	341	50	233	1025
6" ceiling	174	47	143	341	50	233	990
6" ceiling, 4" walls	36	47	143	341	50	233	850
6" ceiling, 4" wall, 4" floor	36	47	52	341	50	233	760
6" ceiling, 4" wall, 4" floor, storm windows & doors	36	47	52	165	28	133	460
12" ceiling, 4" wall, 4" floor, storm windows & doors	36	25	52	165	28	133	440
12" ceiling, 6" wall, 6" floor, storm windows & doors	26	25	39	165	28	133	415

It was desired to compare masonary walls with the frame wall analyzed to see if they have comparable thermal resistances. The typical brick wall below is evaluated for this purpose.



Component	R-value
Outside Air	0.17
Face Brick (4")	0.44
Common Brick (4")	0.80
Air Space	0.97
Wall Board (1/2")	0.45
Inside Air	0.68
TOTAL. .	3.51

It was also desired to evaluate the effect of not heating an unused room. By doing this the interior walls of the room add a thermal resistance. The room analyzed is shown on the next page.



If the room is heated the conductance for that section of the house is:

$$U_H = \frac{A_{\text{outside wall}}}{R_{\text{wall}}} + \frac{A_{\text{window}}}{R_{\text{window}}} + \frac{A_{\text{ceiling}}}{R_{\text{ceiling}}} + \frac{A_{\text{floor}}}{R_{\text{floor}}}$$

$$A_{\text{outside wall}} = (12' \times 10') * 7' - A_{\text{window}} = 124 \text{ ft}^3$$

$$A_{\text{window}} = 30 \text{ ft}^2$$

$$A_{\text{ceiling}} = 12' \times 10' = 120 \text{ ft}^2$$

$$A_{\text{floor}} = 12' \times 10' = 120 \text{ ft}^2$$

Using the R-values for an uninsulated house gives

$$U_H = \frac{124}{3.9} + \frac{30}{0.88} + \frac{120}{3.3} + \frac{120}{8.2} = 117 \text{ Btu/hr/Deg } \Delta T$$

With the room unheated, the effective conductance is determined by combining the conductance of the outside surface with that of the interior wall by:

$$U_x = \frac{1}{1/U_{i.w.} + 1/U_{o.s.}}$$

The interior wall is a 2" x 4" frame wall on 16" centers with 1/2" wall board on either side. The overall resistance is calculated below

Component	R-value
Still Air	0.68
Plaster Board	0.45
Air Space	1.17
Plaster Board	0.45
Still Air	0.68
TOTAL . .	3.43

The door is 1" of wood and has an R-value of 1.25. The overall conductance of the room is then:

$$U_{i.w.} = \frac{A_w}{R_w} + \frac{A_d}{R_d} = \frac{154-21}{3.3} + \frac{21}{1.25} = 55.6$$

With the door closed the total conductance is:

$$U_t = \frac{1}{\frac{1}{55.6} + \frac{1}{117}} = 37.7 \text{ Btu/hr/Deg } \Delta T$$

The reduction in the conductance with the room closed is then:

$$117 - 37.7 = 79 \text{ Btu/hr/Deg } \Delta T$$

Compared to the total conductance of 1300 for the house initially this represents a 6% decrease in heat loss due to lower conduction loss. No decrease in infiltration is considered.

Table 1. Construction Features of Typical House

Nominal Dimensions - 30' x 40', 7 ft. ceilings

Windows - 20, wooden single pane, average size 3' x 5', not weather stripped

Doors - 3, 1" hardwood, not weather stripped, average size 3' x 7'

Table 2. Insulation Considered

1. none
2. 3" ceiling
3. 6" ceiling
4. 6" ceiling, 4" walls
5. 6" ceiling, 4" walls, 4" floor
6. 6" ceiling, 4" walls, 4" floor, storm windows, storm doors
7. 12" ceiling, 4" walls, 4" floor, storm windows, storm doors
8. 12" ceiling, 6" walls, 6" floor, storm windows, storm doors

Table 3. Cost Estimates for Insulation

a) Cost for units of insulation installed

Insulation	New Construction	Existing Structures
3" attic	20¢/ft^2	25¢/ft^2
6" attic	25¢/ft^2	30¢/ft^2
12" attic	35¢/ft^2	40¢/ft^2
4" wall	25¢/ft^2	50¢/ft^2
6" wall *	25¢/ft^2	------
4" floor	25¢/ft^2	35¢/ft^2
6" floor	30¢/ft^2	40¢/ft^2
Storm windows	$35/window	$40/window
Storm doors	$120/door	$130/door

* 6" wall insulation requires 2 x 6 framing and is thus possible only on houses which already have this or new construction. Using 2 x 6 framing on 24" centers actually results in a cheaper, stronger wall.

b) Cost for insulation options

	New	Old
1.	0	0
2.	$240	$300
3.	$300	$360
4.	$490	$740
5.	$790	$1160

Table 3. Continued

b) Cost for insulation options

	New	Old
6.	$1850	$2350
7.	$1970	$2470
8.	$2030	-----

Table 4. Energy Savings with Insulation for Typical House

Insulation Level	% Savings	BTU/YR Savings*
1	0	0
2	21	53×10^6 BTU/yr
3	26	66×10^6 BTU/yr
4	36	91×10^6 BTU/yr
5	44	112×10^6 BTU/yr
6	66 1/2	169×10^6 BTU/yr
7	68 1/2	174×10^6 BTU/yr
8	70 1/2	179×10^6 BTU/yr

* Based on 8000 heating degree days per year. Actual heating requirement, not furnace fuel use. Heating requirements with no insulation are 253×10^6 BTU/yr.

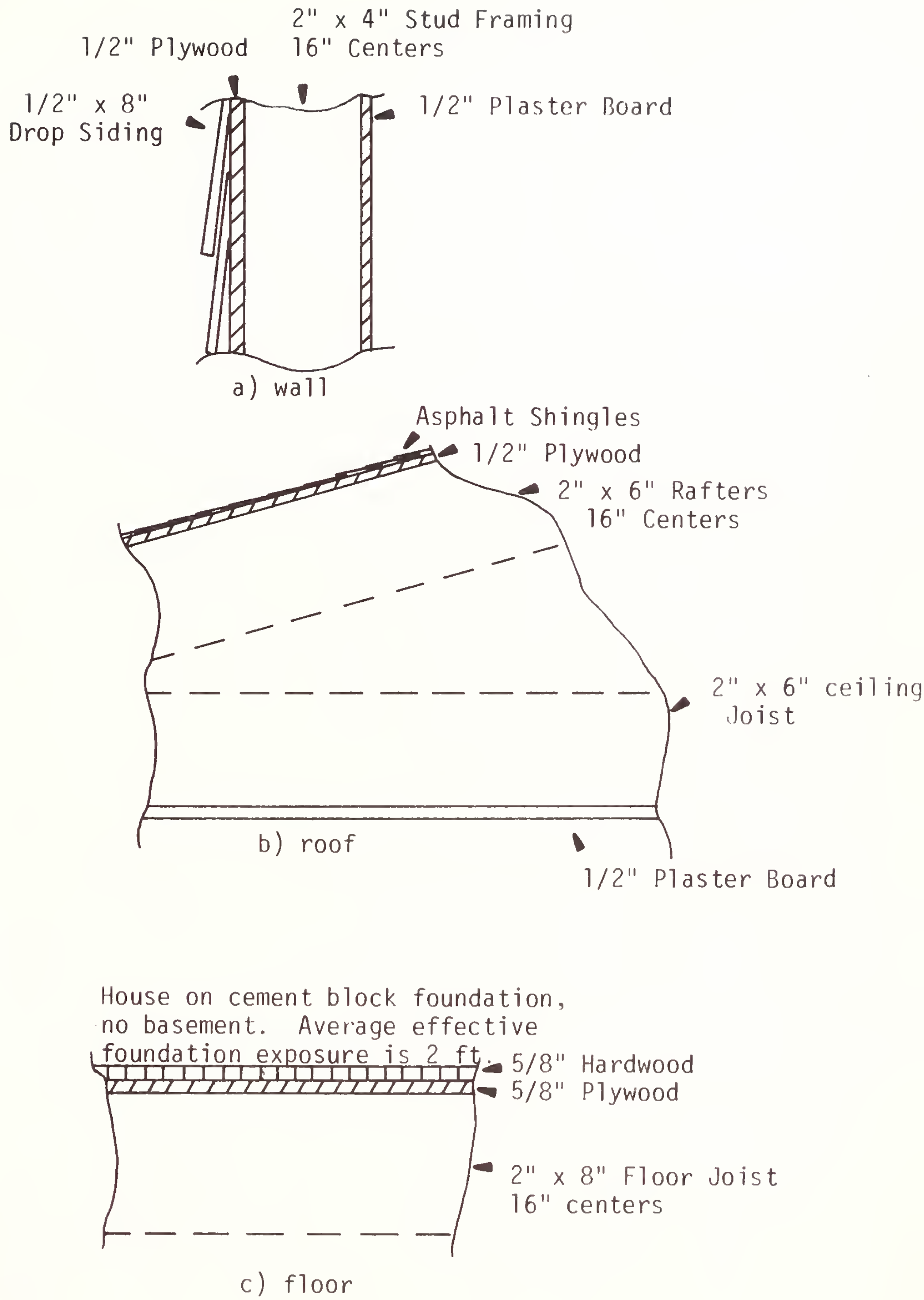


Figure 1.--Construction of Typical House

STRUCTURE OF HOME INSULATION MODEL

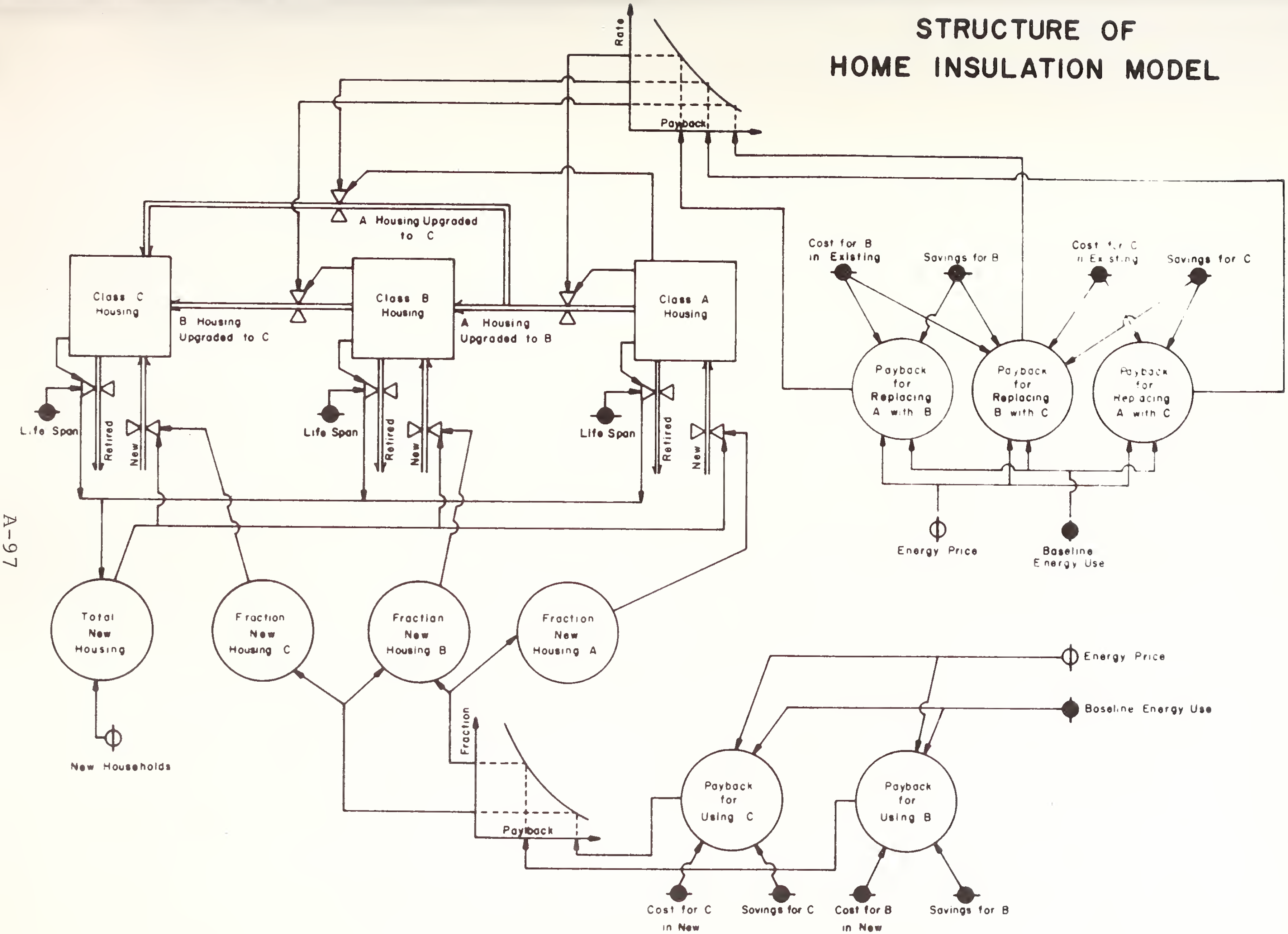


Figure 2

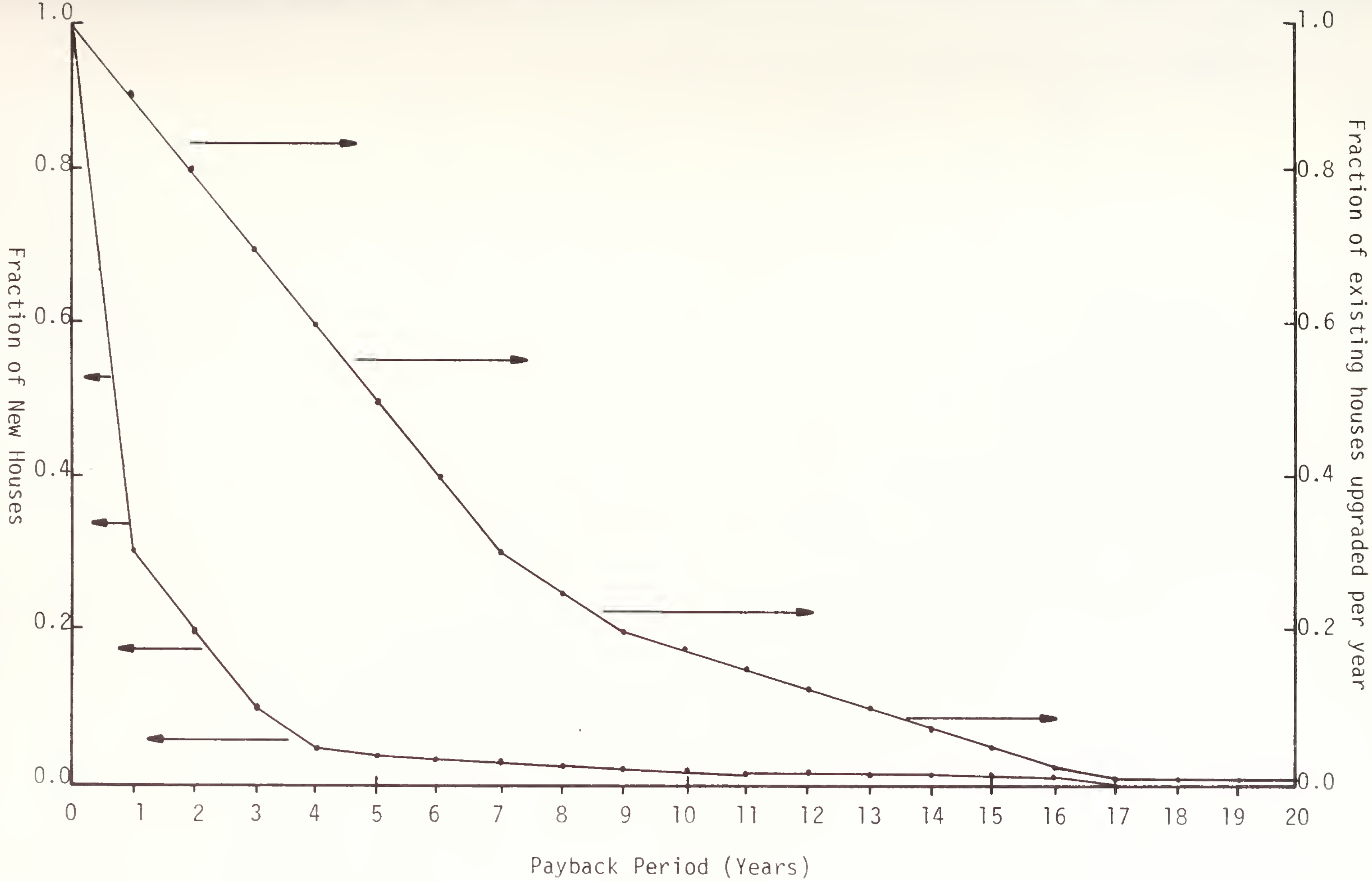


Figure 3.--Upgrading of Existing Houses and Insulation in New Houses as a Function of Payback Period.

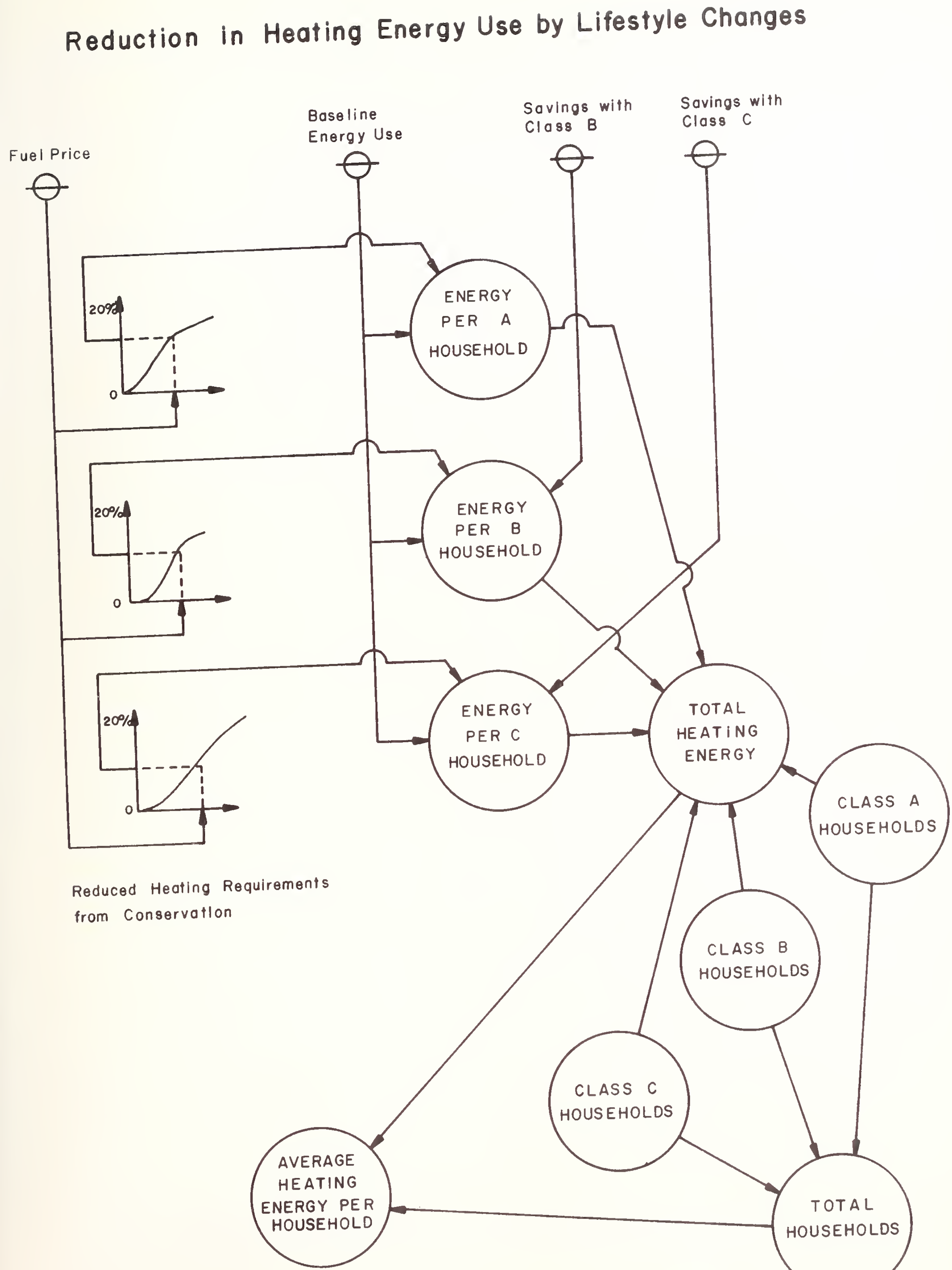


Figure 4.--Calculation of Space Heating Energy Requirements

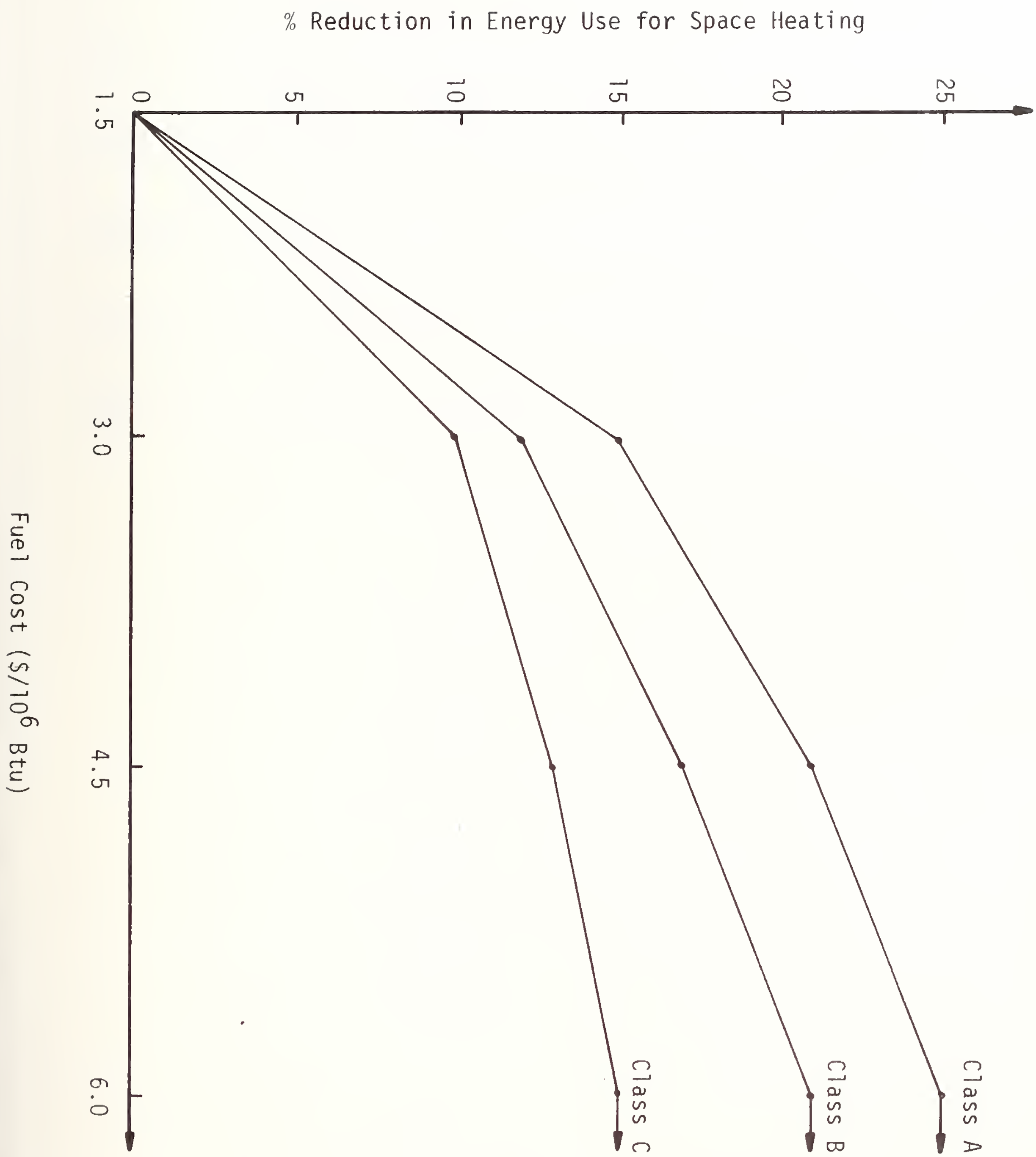


Figure 5.--Energy Savings from Lifestyle Changes

Residential Energy Conservation Sub-Model References

1. Standard Handbook for Mechanical Engineers, edited by Baumeister and Marks, 7th edition, McGraw-Hill, 1967.

2. ASHRAE Handbook of Fundamentals. American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc., 1972.

3. Citizen Action Guide to Energy Conservation. Citizens Advisory Committee on Environmental Quality. The Presidents Council on Environmental Quality, Washington D.C., 1973.

4. Comprehensive Evaluation of Energy Conservation Measures. Appendices, Mathematica, Incorporated. Environmental Protection Agency, 1975.

5. Retrofitting Existing Housing for Energy Conservation: An Economic Analysis. Building Science Series 64, U.S. Department of Commerce, 1974.

6. Cost-Effective Methods to Reduce the Heating and Cooling Energy Requirements of Existing Single-Family Residence. ABT Associates, Incorporated. U.S. Department of Housing and Urban Development, 1976.

APPENDIX B

Computer Program Listing

```
C
C COMMON FOR INPUT/OUTPUT VARIABLES
C
      COMMON /GENRLI/A4,A5,A6,A9,A12,A14,A16,A17,A20,A26,A27,A28,A29,
     2 A30,
     3 AI1(10),AI2(25),AI3(25),AI4(35),A41,A42
      COMMON /AGI/ A1,A2,A3
      COMMON /FORSTI/ A7,A8
      COMMON /GASOI/ A10,A11,A13
      COMMON /COALMI/ A15,A40
      COMMON /MINEI/ A18,A19
      COMMON /SDEMI/ A21,A22,A23,A24,A25
      COMMON /DEMNDI/ A43
      COMMON /OUTPTI/ A39
      COMMON /LABORI/A38
      COMMON /CAPINI/ AI6(35)
      COMMON /ENRDMI/ AI5(5)
      COMMON /DEMOGI/ A31,A32
      COMMON /LANDI/ A33,A34,A36,A37
      COMMON /HHTCNI/ A44,A45,A46
C
C COMMON FOR PARAMETER VARIABLES
C
      COMMON /GENRLP/ IP43,IP50,DT
      COMMON /AGP/ P1,P2,P3,P4,P5,P6,P7,P8,P9,P10,P11,P12,P13
      COMMON /FORSTP/ P14,P15,P16,P17
      COMMON /GASOP/ P18,P19,P20,P21,P22,P23,P24,P25,P104
      COMMON /COALMP/ P26,IP27,IP28,IP29,P93,P94,IP96,P103
      COMMON /MINEP/P30,IP31,IP32,IP33,IP97
      COMMON /SDEMP/P34,P35,P36
      COMMON /DEMNDP/ P37,P38,P39,P102,P40,P41,IP42,PA66(25),PA67(25),
     2  PA68(25),PA69(25)
      COMMON /OUTPTP/ IP44,PA70(25,10),PA71(25,25)
      COMMON /LABORP/ P45,P46,P47,P48,P49,PA72(35),IPA73(35),P100,P101
      COMMON /CAPINP/P51,PA74(35),PA75(35),IPA76(35),PA90(25)
      COMMON /ENRDMP/ IP52,IP53,PA77(5,10),PA78(5,10),PA79(5,35)
      COMMON /DEMOGP/P54,P55,IP56,IP57,IP58,IP59,P60,IP61,PA80(4),
     2PA81(25),PA82(40),PA83(30),PA84(6,45),IP91,IP92,P95
      COMMON /LANDP/P62,P63,P64,P85,P65
      COMMON /HHTCNP/ P106,P107,P108,P109,P110,P111,P112,P113
C
C COMMON FOR STATE VARIABLES
C
      COMMON /AGS/S15,S16
      COMMON /FORSTS/S17,S18
      COMMON /GASOS/S19,S20,S21,S22,S1(50),S2(50),S3(20),S4(20)
      COMMON /COALMS/S23, S37,S5(20)
      COMMON /MINES/S24,S6(20)
      COMMON /SDEMS/S25
      COMMON /OUTPTS/ S38
      COMMON /LABORS/ S26,S27,S28,S39
      COMMON /CAPINS/S34(35),S35(35)
      COMMON /DEMOGS/ S7(6,25),S8(60),S9(60),S10(60),S11(60),S12(60),
     2  S13(60),S14(30)
      COMMON /LANDS/ S29,S30,S31,S32,S33,S36(3)
      COMMON /HHTCNS/ S40,S41,S42,S43
```

```
C COMMON FOR AFNC
      COMMON /AFNCP/ XFNC(75,30,2),IFNC(75,5)
      ILPX=6
      ICRX=5
C READ SIMULATION CONTROL VARIABLES
      READ(ICRX,101) TSTRT,TEND,DT,ISOER,ISCON,ISPRC,ISPNM,IPRNT,IPANT
  101 FORMAT(3E12.0,6I6)
C READ AG PARAMETERS
      READ(ICPX,100) P1,P2,P3,P4,P5,P6
  100 FORMAT(6E12.0)
      READ (ICRX,100) P7,P8,P9,P10,P11,P12
      READ (ICRX,100) P13
C READ FOREST PARAMETERS
      READ (ICRX,100) P14,P15,P16,P17
C READ GASOIL PARAMETERS
      READ (ICRX,100) P18,P19,P20,P21,P22,P23
      READ (ICRX,100) P24,P25,P104
C READ COALMN PARAMETERS
      READ (ICRX,100) P26,P93,P94,P103
      READ (ICRX,200) IP27,IP28,IP29,IP96
  200 FORMAT(12I6)
C READ MINING PARAMETERS
      READ (ICRX,100) P30
      READ (ICRX,200) IP31,IP32,IP33,IP97
C READ SUPDEM PARAMETERS
      READ (ICRX,100) P34,P35,P36
C READ DEMAND PARAMETERS
      READ (ICRX,100) P37,P38,P39,P40,P41,P102
      READ (ICRX,200) IP42,IP43
      READ (ICRX,100) (PA66(J),J=1,25)
      READ (ICRX,100) (PA67(J),J=1,25)
      READ (ICRX,100) (PA68(J),J=1,25)
      READ (ICRX,100) (PA69(J),J=1,25)
C READ OUTPUT PARAMETERS
      READ (ICRX,200) IP44
      DO 10 I=1,25
   10 READ(ICRX,100) (PA70(I,J),J=1,10)
      DO 20 I=1,25
   20 READ(ICRX,100) (PA71(I,J),J=1,25)
C READ LABOR PARAMETERS
      READ (ICRX,100) P45,P46,P47,P48,P49
      READ (ICRX,200) IP50
      READ (ICRX,100) (PA72(J),J=1,35)
      READ (ICRX,200) (IPA73(J),J=1,35)
C READ CAPINV PARAMETERS
      READ (ICRX,100) P51
      READ (ICRX,100) (PA74(J),J=1,35)
      READ (ICRX, 100) (PA75(J),J=1,35)
      READ (ICRX,200) (IPA76(J),J=1,35)
      READ (ICRX,100) (PA90(J),J=1,25)
C READ ENRDMD PARAMETERS
      READ (ICRX,200) IP52,IP53
      READ (ICRX,100) ((PA77(I,J),J=1,10),I=1,5)
      READ (ICRX,100) ((PA78(I,J),J=1,10),I=1,5)
      READ (ICRX,100) ((PA79(I,J),J=1,35),I=1,5)
C READ DEMOG PARAMETERS
      READ (ICRX,100) P54,P55
```

```
      READ (ICRX,200) IP56,IP57,IP58,IP59
      READ (ICRX,100) P60
      READ (ICRX,200) IP61
      READ (ICRX,100) (PA80(J),J=1,4)
      READ (ICRX,100) (PA81(J),J=1,25)
      READ (ICRX,100) (PA82(J),J=1,40)
      READ (ICRX,100) (PA83(J),J=1,30)
      READ (ICRX,100) ((PA84(I,J),J=1,45),I=1,6)
      READ (ICRX,200) IP91,IP92
      READ(ICRX,100) P95
C READ LAND PARAMETERS
      READ (ICRX,100) P62,P63,P64,P85,P65
C READ HHTCON PARAMETERS
      READ(ICRX,100) P106,P107,P108,P109,P110,P111
      READ(ICRX,100) P112,P113
C READ OTHER PARAMETERS
      READ (ICRX,100) P86,P87,P88,P89
C READ AG STATE VARIABLES
      READ (ICRX,100) S15,S16
C READ FOREST STATE VARIABLES
      READ (ICRX,100) S17,S18
C READ GASOIL STATE VARIABLES
      READ (ICRX,100) S19,S20,S21,S22
      READ (ICRX,100) (S1(J),J=1,50)
      READ (ICRX,100) (S2(J),J=1,50)
C READ COALMN STATE VARIABLES
      READ (ICRX,100) S23,S37
      READ (ICRX,100) (S5(J),J=1,20)
C READ MINING STATE VARIABLES
      READ (ICRX,100) S24
      READ (ICRX,100) (S6(J),J=1,20)
C READ SUPDEM STATE VARIABLES
      READ (ICRX,100) S25
C READ OUTPUT STATE VARIABLES.
      READ (ICRX,100) S38
C READ LABOR STATE VARIABLES
      READ (ICRX,100) S26,S27,S28,S39
C READ CAPINV STATE VARIABLES
      READ (ICRX,100) (S34(J),J=1,35)
      READ (ICRX,100) (S35(J),J=1,35)
C READ DEMOG STATE VARIABLES
      READ (ICRX,100) ((S7(I,J),J=1,25),I=1,6)
      READ (ICRX,100) (S8(J),J=1,60)
      READ (ICRX,100) (S9(J),J=1,60)
      READ (ICRX,100) (S10(J),J=1,60)
      READ (ICRX,100) (S11(J),J=1,60)
      READ (ICRX,100) (S12(J),J=1,60)
      READ (ICRX,100) (S13(J),J=1,60)
      READ (ICRX,100) (S14(J),J=1,30)
C READ LAND STATE VARIABLES
      READ (ICRX,100) S29,S30,S31,S32,S33
      READ (ICRX,100) (S36(J),J=1,3)
C READ HHTCON STATE VARIAPLES
      READ(ICRX,100) S40,S41,S42,S43
C READ OTHER SCENARIO VARIABLES
      READ(ICRX,100) (AI3(I),I=1,25)
      READ(ICRX,100) (AI6(I),I=1,35)
```

```
      READ(ICRX,100) A26,A27,A30,A40
      READ(ICRX,100) V1,V2
C READ FUNCTION INFO
      READ (ICRX,200) NFNC
      DO 250 I=1,NFNC
      READ (ICRX,200) (IFNC(I,J),J=1,5)
      L=IFNC(I,4)
      READ (ICRX,100) ((XFNC(I,J,K),J=1,L),K=1,2)
  250 CONTINUE
      DO 4321 I=1,20
      S3(I)=0.
      S4(I)=0.
      DO 4321 K=I,50
      J=K-I+1
      X=J
      CALL AFNC(X,Y,3)
      S3(I)=S3(I)+S1(J)*Y
      CALL AFNC(X,Y,7)
 4321 S4(I)=S4(I)+S2(J)*Y
C
CPRINT ALL INPUTS
C
      I=TSTRT
      J=TEND
      PRINT 3000,I,J,DT
 3000 FORMAT('1STARTING YEAR =',I5/' ENDING YEAR =',I5/
     1 ' TIME STEP =',F5.1,' YEARS'///)
      PRINT 3001,ISOER,ISCON,ISPRC,ISPRM
 3001 FORMAT(' SCENARIOS',5X,4I3)
      IF(IPRNT.EQ.0) GO TO 7000
      PRINT 3010
 3010 FORMAT(' INPUT VALUES'/)
      KTS=1
      KTE=6
      PRINT 3020,KTS,KTE,P1,P2,P3,P4,P5,P6
      KTS=7
      KTE=12
      PRINT 3020,KTS,KTE,P7,P8,P9,P10,P11,P12
      KTS=13
      PRINT 3030,KTS,P13
      KTS=14
      KTE=17
      PRINT 3020,KTS,KTE,P14,P15,P16,P17
      KTS=18
      KTE=23
      PRINT 3020,KTS,KTE,P18,P19,P20,P21,P22,P23
      KTS=24
      KTE=25
      PRINT 3020,KTS,KTE,P24,P25
      KTS=104
      PRINT 3031,KTS,P104
      KTS=26
      PRINT 3030,KTS,P26
      KTS=103
      PRINT 3031,KTS,P103
      KTS=27
      KTE=29
```

```
PRINT 3040,KTS,KTE,IP27,IP28,IP29
KTS=96
PRINT 3060,KTS,IP96
KTS=30
PRINT 3030,KTS,P30
KTS=31
KTE=33
PRINT 3040,KTS,KTE,IP31,IP32,IP33
KTS=97
PRINT 3060,KTS,IP97
KTS=34
KTE=36
PRINT 3020,KTS,KTE,P34,P35,P36
KTS=37
KTE=41
PRINT 3020,KTS,KTE,P37,P38,P39,P40,P41
KTS=102
PRINT 3031,KTS,P102
KTS=42
KTE=43
PRINT 3040,KTS,KTE,IP42,IP43
KTS=66
PRINT 3050,KTS,(PA66(J),J=1,25)
KTS=67
PRINT 3050,KTS,(PA67(J),J=1,25)
KTS=68
PRINT 3050,KTS,(PA68(J),J=1,25)
KTS=69
PRINT 3050,KTS,(PA69(J),J=1,25)
KTS=44
PRINT 3060,KTS,IP44
KTS=70
PRINT 3050,KTS,(( PA70(I,J),J=1,10),I=1,25)
KTS=71
PRINT 3050,KTS,((PA71(I,J),J=1,25),I=1,25)
KTS=45
KTE=49
PRINT 3020,KTS,KTE,P45,P46,P47,P48,P49
KTS=100
KTE=101
PRINT 3021,KTS,KTE,P100,P101
KTS=50
PRINT 3060,KTS,IP50
KTS=72
PRINT 3050,KTS,(PA72(J),J=1,35)
KTS=73
PRINT 3070,KTS,(IPA73(J),J=1,35)
KTS=51
PRINT 3030,KTS,P51
KTS=74
PRINT 3050,KTS,(PA74(J),J=1,35)
KTS=75
PRINT 3050,KTS,(PA75(J),J=1,35)
KTS=76
PRINT 3070,KTS,(IPA76(J),J=1,35)
KTS=90
PRINT 3050,KTS,(PA90(J),J=1,25)
```

```
      KTS=52
      KTE=53
      PRINT 3040,KTS,KTE,IP52,IP53
      KTS=77
      PRINT 3050,KTS,((PA77(I,J),J=1,10),I=1,5)
      KTS=78
      PRINT 3050,KTS,((PA78(I,J),J=1,10),I=1,5)
      KTS=79
      PRINT 3050,KTS,((PA79(I,J),J=1,35),I=1,5)
      KTS=54
      KTE=55
      PRINT 3020,KTS,KTE,P54,P55
      KTS=56
      KTE=59
      PRINT 3040,KTS,KTE,IP56,IP57,IP58,IP59
      KTS=60
      PRINT 3030,KTS,P60
      KTS=61
      PRINT 3060,KTS,IP61
      KTS=80
      PRINT 3050,KTS,(PA80(J),J=1,4)
      KTS=81
      PRINT 3050,KTS,(PA81(J),J=1,25)
      KTS=82
      PRINT 3050,KTS,(PA82(J),J=1,40)
      KTS=83
      PRINT 3050,KTS,(PA83(J),J=1,30)
      KTS=84
      PRINT 3050,KTS,((PA84(I,J),J=1,45),I=1,6)
      KTS=91
      KTE=92
      PRINT 3040,KTS,KTE,IP91,IP92
      KTS=95
      PRINT 3030,KTS,P95
      PRINT 3080,P62,P63,P64,P85,P65
      PRINT 3085,P86,P87,P88,P89,P93,P94
      KTS=106
      KTE=111
      PRINT 3021,KTS,KTE,P106,P107,P108,P109,P110,P111
      KTS=112
      KTE=113
      PRINT 3021,KTS,KTE,P112,P113
 3085 FORMAT(' P86, P87, P88, P89,  P93, P94',T40,4G12.5/T40,2G12.5)
 3080 FORMAT(' P62, P63, P64, P85, P65',T40,5G12.5)
 3020 FORMAT(' P',I2,' - P',I2,T40,6G12.5)
 3021 FORMAT(' P',I3,' - P',I3,T40,6G12.5)
 3030 FORMAT(' P',I2,T40,G12.3)
 3031 FORMAT(' P',I3,T40,6G12.5)
 3040 FORMAT(' IP',I2,' - IP',I2,T40,6I12)
 3050 FORMAT(' PA',I2,(T40,6G12.5))
 3060 FORMAT(' IP',I2,T40,I12)
 3070 FORMAT(' IPA',I2,(T40,6I12))
      KTS=3
      PRINT 3180,KTS,(AI3(J),J=1,25)
      KTS=6
      PRINT 3180,KTS,(AI6(J),J=1,35)
      PRINT 3120,A26,A27,A30,A40,V1,V2
```

```
3120 FORMAT(' A26,A27,A30,A40,V1,V2',T40,6G12.5)
3180 FORMAT(' AI',I2,(T40,6G12.5))
     PRINT 3090
3090 FORMAT('1')
     KTS=15
     KTE=16
     PRINT 3100,KTS,KTE,S15,S16
     KTS=17
     KTE=18
     PRINT 3100,KTS,KTE,S17,S18
     KTS=19
     KTE=22
     PRINT 3100,KTS,KTE,S19,S20,S21,S22
     KTS=1
     PRINT 3110,KTS,(S1(J),J=1,50)
     KTS=2
     PRINT 3110,KTS,(S2(J),J=1,50)
     KTS=3
     PRINT 3110,KTS,(S3(J),J=1,20)
     KTS=4
     PRINT 3110,KTS,(S4(J),J=1,20)
     KTS=23
     PRINT 3110,KTS,S23
     KTS=37
     PRINT 3110,KTS,S37
     KTS=5
     PRINT 3110,KTS,(S5(J),J=1,20)
     KTS=24
     PRINT 3110,KTS,S24
     KTS=6
     PRINT 3110,KTS,(S6(J),J=1,20)
     KTS=25
     PRINT 3110,KTS,S25
     KTS=38
     PRINT 3110,KTS,S38
     KTS=26
     KTE=28
     PRINT 3100,KTS,KTE,S26,S27,S28
     KTS=39
     PRINT 3110,KTS,S39
     KTS=34
     PRINT 3110,KTS,(S34(J),J=1,35)
     KTS=35
     PRINT 3110,KTS,(S35(J),J=1,35)
     KTS=29
     KTE=33
     PRINT 3100,KTS,KTE,S29,S30,S31,S32,S33
     KTS=36
     PRINT 3110,KTS,(S36(J),J=1,3)
     KTS=37
     PRINT 3110,KTS,S37
     KTS=40
     KTE=43
     PRINT 3100,KTS,KTE,S40,S41,S42,S43
3100 FORMAT(' S',I2,' - S',I2,T40,6G12.5)
3110 FORMAT(' S',I2,(T40,6G12.5))
     PRINT 3090
```

```
      PRINT 3090
      PRINT 3140,NFNC
 3140 FORMAT(' NFNC =',I4)
      DO 3150 I=1,NFNC
      PRINT 3170,I,(IFNC(I,J),J=1,5)
      L=IFNC(I,4)
      PRINT 3160,((XFNC(I,J,K),J=1,L),K=1,2)
 3150 CONTINUE
 3160 FORMAT(' XFNC',(T40,6G12.5))
 3170 FORMAT(' IFNC',I5,(T40,6I12))
 7000 CONTINUE
C
C END OF INPUT PRINT
C
      TIME=TSTRT
      ICOUNT=TSTRT+.00001
  300 CONTINUE
C DISCRETE PARAMETER CHANGES
      IF(ICOUNT.EQ.1980) P14=P14*1.1
      IF(ICOUNT.EQ.1990) P14=P14*1.05
      IF(ICOUNT.EQ.1980) P86=P86*1.05
      IF(ICOUNT.EQ.1985) P86=P86*1.05
      IF(ICOUNT.EQ.1980) P15=P15*1.03
      IF(ICOUNT.EQ.1985) P15=P15*1.03
      CALL AFNC(TIME,A2,20)
      CALL AFNC(TIME,A10,21)
      CALL AFNC(TIME,A11,22)
      CALL AFNC(TIME,A15,23)
      CALL AFNC(TIME,A18,24)
      CALL AFNC(TIME,A25,25)
      CALL AFNC(TIME,A31,26)
      CALL AFNC(TIME,A32,27)
      CALL AFNC(TIME,A36,28)
      CALL AFNC(TIME,A37,29)
      CALL AFNC(TIME,A40,32)
      CALL AFNC(TIME,A,33)
      IF(ISOER.EQ.1) GO TO 350
      PA72(28)=A
      CALL AFNC(TIME,A,34)
      PA72(27)=A
      CALL AFNC(TIME,A,35)
      PA72(26)=A
      CALL AFNC(TIME,A,36)
      PA72(1)=A
      CALL AFNC(TIME,A,37)
      PA72(2)=A
      PA72(3)=A
      PA72(4)=A
      PA72(5)=A
      CALL AFNC(TIME,A,38)
      PA72(25)=A
      CALL AFNC(TIME,A,39)
      PA72(30)=A
      CALL AFNC(TIME,A,40)
      PA72(29)=A
      CALL AFNC(TIME,A,41)
      PA72(10)=A
```

```
      PA72(6)=A
      PA72(7)=A
      PA72(8)=A
      PA72(9)=A
      CALL AFNC(TIME,A,42)
      PA72(11)=A
      CALL AFNC(TIME,A,43)
      PA72(12)=A
      CALL AFNC(TIME,A,44)
      PA72(13)=A
      CALL AFNC(TIME,A,45)
      PA72(14)=A
      CALL AFNC(TIME,A,46)
      PA72(15)=A
      PA72(16)=A
      CALL AFNC(TIME,A,47)
      PA72(17)=A
      CALL AFNC(TIME,A,48)
      PA72(18)=A
      PA72(19)=A
      PA72(20)=A
      PA72(23)=A
      CALL AFNC(TIME,A,49)
      PA72(21)=A
      PA72(22)=A
      CALL AFNC(TIME,A,50)
      PA72(24)=A
  350 CONTINUE
      IF(ISCON.EQ.0) GO TO 360
      A45=A3
      CALL AFNC(TIME,A44,62)
      CALL AFNC(TIME,Z,63)
      P109=P109*Z
      P110=P110*Z
      P111=P111*Z
      P112=P112*Z
      CALL AFNC(TIME,P106,64)
      CALL HHTCON
      PA77(2,1)=A46*.001
  360 CONTINUE
      CALL AFNC(TIME,P100,51)
      CALL AFNC(TIME,P101,52)
      CALL AFNC(TIME,P45,53)
      A1=S30
      A3=S28
      CALL AG
      A7=S29
      CALL FOREST
      CALL GASOIL
      CALL COALMN
      CALL MINING
      A21=A8*P86
      A22=A12*P36+A13*P87
      A23=A16*P88
      A24=A19*P89
      CALL SUPDEM
      A26=S39
```

```
      A43=S38
      CALL DEMAND
      CALL OUTPUT
      CALL LABOR
      CALL CAPINV
C
C INDUSTRIAL SWITCHES
C
      IF(ISPRC.EQ.0) GO TO 6400
      IF(ICOUNT.NE.1976) GO TO 6000
      PA79(2,25)=17.27
      PA79(2,9)=61.24
 6000 CONTINUE
      IF(ICOUNT.NE.1977) GO TO 6100
      PA79(2,25)=17.1
      PA79(2,30)=18.49
      PA79(2,29)=18.95
 6100 CONTINUE
      IF(ICOUNT.NE.1978) GO TO 6200
      PA79(2,25)=17.04
      PA79(2,9)=18.69
      PA79(2,2)=8.81
      PA79(2,3)=8.81
      PA79(2,4)=8.81
      PA79(2,5)=8.81
      PA79(2,30)=17.79
 6200 CONTINUE
      IF(ICOUNT.NE.1979) GO TO 6300
      PA79(2,25)=16.18
      PA79(2,30)=17.1
 6300 CONTINUE
      IF(ICOUNT.NE.1980) GO TO 6400
      PA79(2,30)=16.4
 6400 CONTINUE
C
C END OF INDUSTRIAL SWITCHES
C
      CALL ENROM
C
C SUBSTITUTION IN INDUSTRY
C
      IF(ISPRM.EQ.0) GO TO 777
      IF(ICOUNT.LT.1980) GO TO 777
      IF(ICOUNT.GT.1980) GO TO 776
      X29=PA79(2,29)
      X25=PA79(2,25)
      X2=PA79(2,2)
      X7=PA79(2,7)
      GO TO 777
  776 A=PA79(2,29)
      CALL SUBST(X29,A,1.,.65E-06,.5,.3,1.,TIME)
      PA79(2,29)=A
      A=PA79(2,25)
      CALL SUBST(X25,A,1.,.65E-06,.5,.3,1.,TIME)
      PA79(2,25)=A
      A=PA79(2,2)
      CALL SUBST(X2,A,.8,.65E-06,.5,.3,1.,TIME)
```

```
      PA79(2,2)=A
      PA79(2,3)=A
      PA79(2,4)=A
      PA79(2,5)=A
      A=PA79(2,7)
      CALL SUBST(X7,A,.8,1.125E-06,.8,.8,1.,TIME)
      PA79(2,7)=A
  777 CONTINUE
      CALL DEMOG
      A33=(A30-V2)/DT
      V2=A30
      A34=(A38-V1)/DT
      V1=A38
      CALL LAND
C
C TEMPORARY OUTPUT OF RESULTS
C
 3900 CONTINUE
      IF(IPRNT2.NE.0) GO TO 7300
      PRINT 4000,TIME
 4000 FORMAT('1RESULTS THROUGH',F6.0///)
      IF(IPRNT.EQ.0) GO TO 7100
      KTS=15
      KTE=16
      PRINT 4010,KTS,KTE,S15,S16
      KTS=17
      KTE=18
      PRINT 4010,KTS,KTE,S17,S18
      KTS=19
      KTE=22
      PRINT 4010,KTS,KTE,S19,S20,S21,S22
      KTS=1
      PRINT 4020,KTS,(S1(J),J=1,50)
      KTS=2
      PRINT 4020,KTS,(S2(J),J=1,50)
      KTS=3
      PRINT 4020,KTS,(S3(J),J=1,20)
      KTS=4
      PRINT 4020,KTS,(S4(J),J=1,20)
      KTS=23
      PRINT 4020,KTS,S23
      KTS=5
      PRINT 4020,KTS,(S5(J),J=1,20)
      KTS=24
      PRINT 4020,KTS,S24
      KTS=6
      PRINT 4020,KTS,(S6(J),J=1,20)
      KTS=25
      PRINT 4020,KTS,S25
      KTS=38
      PRINT 4020,KTS,S38
      KTS=26
      KTE=28
      PRINT 4010,KTS,KTE,S26,S27,S28
      KTS=39
      PRINT 4020,KTS,S39
      KTS=34
```

```
      PRINT 4020,KTS,(S34(J),J=1,35)
      KTS=35
      PRINT 4020,KTS,(S35(J),J=1,35)
      KTS=29
      KTE=33
      PRINT 4010,KTS,KTE,S29,S30,S31,S32,S33
      KTS=36
      PRINT 4020,KTS,(S36(J),J=1,3)
      KTS=40
      KTE=43
      PRINT 4010,KTS,KTE,S40,S41,S42,S43
 4010 FORMAT(' S',I2,' - S',I2,T40,6G12.5)
 4020 FORMAT(' S',I2,(T40,6G12.5))
 7100 CONTINUE
      PRINT 5000
 5000 FORMAT('1')
      KTS=1
      KTE=6
      PRINT 5010,KTS,KTE,A1,A2,A3,A4,A5,A6
      KTS=7
      KTE=9
      PRINT 5010,KTS,KTE,A7,A8,A9
      KTS=10
      KTE=14
      PRINT 5010,KTS,KTE,A10,A11,A12,A13,A14
      KTS=15
      KTE=17
      PRINT 5010,KTS,KTE,A15,A16,A17
      KTS=18
      KTE=20
      PRINT 5010,KTS,KTE,A18,A19,A20
      KTS=21
      KTE=25
      PRINT 5010,KTS,KTE,A21,A22,A23,A24,A25
      KTS=1
      PRINT 5020,KTS,(AI1(J),J=1,10)
      KTS=26
      PRINT 5030,KTS,A26
      KTS=3
      PRINT 5020,KTS,(AI3(J),J=1,25)
      KTS=2
      PRINT 5020,KTS,(AI2(J),J=1,25)
      KTS=4
      PRINT 5020,KTS,(AI4(J),J=1,35)
      KTS=27
      KTE=29
      PRINT 5010,KTS,KTE,A27,A28,A29
      KTS=30
      PRINT 5030,KTS,A30
      KTS=5
      PRINT 5020,KTS,(AI5(J),J=1,5)
      KTS=6
      PRINT 5020,KTS,(AI6(J),J=1,35)
      KTS=31
      KTE=32
      PRINT 5010,KTS,KTE,A31,A32
      KTS=33
```

```
      KTE=34
      PRINT 5010,KTS,KTE,A33,A34
      KTS=36
      KTE=39
      PRINT 5010,KTS,KTE,A36,A37,A38,A39
      KTS=40
      PRINT 5030,KTS,A40
      KTS=41
      KTE=43
      PRINT 5010,KTS,KTE,A41,A42,A43
 5010 FORMAT(' A',I2,' - A',I2,T40,6G12.5)
 5020 FORMAT(' AI',I2,(T40,6G12.5))
 5030 FORMAT(' A',I2,T40,G12.5)
 7200 CONTINUE
      IF(TIME.GE.TEND) STOP
      TIME=TIME+DT
      ICOUNT=TIME+.00001
      GO TO 300
 7300 CONTINUE
      PRINT 7400,TIME,AI5
      GO TO 7200
 7400 FORMAT(1X,F6.0/' AI5',T20,6G14.5)
      END
```

```
C SUBROUTINE AG
      SUBROUTINE AG
      COMMON /AGI/ AL,P,WR
      COMMON /AGP/ PL,PO,OLP,FTR,RA,PLF,PTI,TF,SALV,ALEVI,AKDEP,ALP,A
      COMMON /AGS/AKO,AKF
      COMMON /GENRLI/ ANFRI,Y,TI,XYZ123(108)
      COMMON /GENRLP/ XYZ124(2),DT
C AGRICULTURE OUTPUT
      TK=AKO+AKF
      Y=A*TK**ALP*AL**(1.-ALP)
      ALR=Y/OLP
      ALE=ALR*WR
      ET=FTR*AL*PL
      DOE=Y*PO
      B=RA*AKF
      C=PLF*AL*PL*RA
      EI=B+C
      D=Y*P
      ANFR=D-(DOE+EI+ALE+ET)
C CAPITAL FORMATION
      SX=0
      AX=0.
      IF(ANFR.GT.0) AX=ANFR*PTI
      IF(ANFR.GT.-TF*Y) GO TO 100
      SX=(-ANFR-(TF*Y))/SALV
  100 DX=AX*ALEVI
      EX=AKF*AKDEP
      FX=AKO*AKDEP
      GX=FX+SX
      AKO=AKO+(AX-GX)*DT
      AKF=AKF+(DX-EX)*DT
      TI=AX+DX
      ANFRI=ANFR-AX
      RETURN
      END
```

```
C SUBROUTINE FOREST
      SUBROUTINE FOREST
      COMMON /FORSTI/ TT,CR
      COMMON /FORSTP/ AC,FCR,DR,CT
      COMMON /FORSTS/TAC,CAP
      COMMON /GENRLI/ XYZ123(3),CFR,XYZ124(107)
      COMMON /GENRLP/ XYZ125(2),DT
C FOREST OUTPUT
      TC=AC*TT
      TCR=TAC*FCR
      ACN=TCR-CAP
      IF(ACN.LT.0) ACN=0
      DEP=CAP*DR
      CFR=(ACN/CT)+DEP
      CRM=CAP/FCR
      DIF=TAC-CRM
      IF(DIF.GT.0) CR=CRM
      IF(DIF.LE.0) CR=TAC
      TAC=TAC+(TC-CR)*DT
      CAP=CAP+(CFR-DEP)*DT
      RETURN
      END
```

```
C SUBROUTINE GASOIL
      SUBROUTINE GASOIL
      COMMON /GASOI/ OP,GP,TGP
      COMMON /GASOP/ GOR,OGR,CCP,DC,GDOE,ODGE,DPT,CC,DISCR
      COMMON /GASOS/AFO,AFG,ODI,GDI,PRO(50),PRG(50),CAPO(20),CAPG(20)
      COMMON /GENRLI/ XYZ123(4),TOP,TOGI,XYZ124(105)
C  DO OPERATIONS INVOLVING SUMMING OF PRODUCING FIELDS
C  AGE-QUANTITY LEVELS
      ICAO=1.
      ICAG=1.
      TDO=AFO
      TDG=AFG
      DO 50 I=1,50
      J=51-I
      A=PRO(J)/2.
      TDO=TDO+A
      IF(ICAO.NE.1) GO TO 25
      CALL AFNC(TDO,PCMO,54)
      OPADJ=OP/PCMO
      CALL AFNC(OPADJ,X,4)
      ICO=X+1.
      IF(ICO.GT.J) ICAO=ICO
   25 TDO=TDO+A
      A=PRG(J)/2.
      TDG=TDG+A
      IF(ICAG.NE.1) GO TO 50
      CALL AFNC(TDG,PCMG,55)
      GPADJ=GP/PCMG
      CALL AFNC(GPADJ,X,8)
      ICG=X+1.
      IF(ICG.GE.J) ICAG=ICG
   50 TDG=TDG+A
      CALL AFNC(TDO,PCMO,54)
      OPADJ=OP/PCMO
      CALL AFNC(OPADJ,X,4)
      ICO=X+1.
      CALL AFNC(TDG,PCMG,55)
      GPADJ=GP/PCMG
      CALL AFNC(GPADJ,X,8)
      ICG=X+1.
      TDO=AFO
      TDG=AFG
      DOP=0.
      DGP=0.
      OIP=0.
      GIP=0.
      OILCAP=0.
      GASCAP=0.
      OILPEX=0.
      GASPEX=0.
      OILINC=0.
      GASINC=0.
      DO 100 I=1,50
      J=51-I
      X=J
      DISCNT=EXP(-X*DISCR)
```

```
      A=PRO(J)
      TDO=TDO+A/2.
      IF(J.GT.ICAO) GO TO 60
      CALL AFNC(X,Y,1)
      DOP=DOP+Y*A
      CALL AFNC(TDO,Z,54)
      CALL AFNC(X,Y,3)
      OIR=OIR+Y*A*Z
   60 TDO=TDO+A/2.
      IF(J.GT.ICO) GO TO 70
      CALL AFNC(X,W,1)
      CALL AFNC(X,Y,2)
      CALL AFNC(X,Z,3)
      OILINC=OILINC+W*OP*DISCNT
      OILPEX=OILPEX+Y*DISCNT*PCMO
      OILCAP=OILCAP+Z*DISCNT*PCMO
   70 A=PRG(J)
      TDG=TDG+A/2.
      IF(J.GT.ICAG) GO TO 80
      CALL AFNC(X,Y,5)
      DGP=DGP+Y*A
      CALL AFNC(TDG,Z,55)
      CALL AFNC(X,Y,7)
      GIR=GIR+Y*A*Z
   80 TDG=TDG+A/2.
      IF(J.GT.ICG) GO TO 90
      CALL AFNC(X,W,5)
      CALL AFNC(X,Y,6)
      CALL AFNC(X,Z,7)
      GASINC=GASINC+W*GP*DISCNT
      GASPEX=GASPEX+Y*DISCNT*PCMG
      GASCAP=GASCAP+Z*DISCNT*PCMG
   90 TDG=TDG+A/2.
  100 CONTINUE
C  TOTAL CAPITAL
      CAPOT=0.
      CAPGT=0.
      DO 110 I=1,20
      CAPOT=CAPOT+CAPO(I)
  110 CAPGT=CAPGT+CAPG(I)
C  CAPITAL EXPENSE
      CEO=CAPOT*CCP
      CEG=CAPGT*CCP
C  PRODUCTION
      GIP=GOR*DOP
      OIP=OGR*DGP
      TOP=DOP+OIP
      TGP=DGP+GIP
C  INCOME FOR PRODUCTION
      OIN=DOP*OP+GIP*GP
      GIN=DGP*GP+OIP*OP
C  PRODUCTION PROFIT
      OPP=OILINC-OILPEX-OILCAP
      GPP=GASINC-GASPEX-GASCAP
C
C  EXPLORATION
C
```

```
C   DRILLING ACTIVITY
      ODR=ODI/(DPT*DC)
      GDR=GDI/(DPT*DC)
C   DISCOVERY RATES
      CALL AFNC(TDO,DRO,9)
      CALL AFNC(TDG,DRG,10)
      DOD=ODR/DRO
      DGD=GDR/DRG
      GDO=DOD*GDOE
      ODG=DGD*ODGE
      TOD=DOD+ODG
      TGD=DGD+GDO
C   'INCOME' EXPENSE RETURN
      OEI=DOD*OPP+GDO*GPP
      GEI=DGD*GPP+ODG*OPP
      CEPO=ODI*CC
      CEPG=GDI*CC
      PREO=OEI-CEPO
      PREG=GEI-CEPG
      PROL=PREO/ODI
      PRGA=PREG/GDI
      CALL AFNC(PROL,Y,11)
      RIO=Y*ODI
      CALL AFNC(PRGA,Y,11)
      RIG=Y*GDI
C   CAPITAL 'DEPRICIATION'
      DPRO=ODI/DPT
      DPRG=GDI/DPT
C   UPDATE LEVELS
C   PRODUCING FIELDS
      IF(ICAO.GE.50) AFO=AFO+PRO(50)
      IF(ICAG.GE.50) AFG=AFG+PRG(50)
      DO 120 I=2,50
      J=50-I+2
      IF(J.LE.ICAO) PRO(J)=PRO(J-1)
      IF(J.LE.ICAG) PRG(J)=PRG(J-1)
      IF(J-1.EQ.ICAO) PRO(J)=PRO(J)+PRO(J-1)
      IF(J-1.EQ.ICAG) PRG(J)=PRG(J)+PRG(J-1)
  120 CONTINUE
      PRO(1)=TOD
      PRG(1)=TGD
C   PRODUCTION CAPATAL
      DO 130 I=2,20
      J=20-I+2
      CAPO(J)=CAPO(J-1)
  130 CAPG(J)=CAPG(J-1)
      CAPO(1)=OIR
      CAPG(1)=GIR
C   EXPLORATION INVESTMENT
      ODI=ODI+RIO-DPRO
      GDI=GDI+RIG-DPRG
      TOGI=OIR+GIR+RIO+RIG
      RETURN
      END
```

```
C SUBROUTINE COALMN
      SUBROUTINE COALMN
      COMMON /COALMI/ PRCS,PRST
      COMMON /COALMP/CC,K1,K2,K3,FDRP,FIRP,K4,ENTRY
      COMMON /COALMS/TM,PRC,AIN(20)
      COMMON /GENRLI/ XYZ123(6),AO,AI,XYZ124(103)
      CALL AFNC(TM,CI,K3)
      CALL AFNC(TM,ACM,K1)
      A=PRC/ACM
      CALL AFNC(A,FO,K2)
      AACM=0.
      X=0.
      L=0
  100 CALL AFNC(X,Y,K4)
      AACM=AACM+Y
      X=X+.01
      IF(X.GT.FO) GO TO 150
      L=L+1
      IF(L.LE.99) GO TO 100
  150 AACM=AACM/L
      TI=0.
      DO 200 I=1,20
  200 TI=TI+AIN(I)
      CLO=TI/CI
      AO=CLO*FO
      GI=AO*PRC
      EM=AO*AACM*ACM
      EC=TI*CC
      P=GI-EM-EC
      IF(TI.LE.0.0) PR=0.0
      IF(TI.GT.0.0) PR=P/TI
      CALL AFNC(PR,RI,11)
      AI=RI*TI
      IF(AO/PRST.LT.0.5) PSE=1.0
      IF(AO/PRST.GE.0.5) PSE=1.5-AO/PRST
      IF(PSE.LT.0.0) PSE=0
      AI=AI*PSE
C     MARKET ENTRY EFFECT
      USM=PRST-AO
      IF(USM.LT.0.) USM=0.
      PRF=PR
      IF(PRF.LT.0.)PRF=0
      IF(PRF.GT.10.) PRF=10
      AI=AI+USM*CI*PRF*ENTRY
C  UPDATE LEVELS
      TM=TM+AO
      DO 300 I=2,20
      J=20-I+2
  300 AIN(J)=AIN(J-1)
      AIN(1)=AI
C      PRICE ADJUSTMENT
      FOPD=(AO-PRST)/PRST
      DPRC=0.0
      IF(FOPD.GT.0.) DPRC=-FOPD*FDRP*PRC
      IF(FOPD.LE.0.0) DPRC=(PRCS-PRC)*FIRP
      PRC=PRC+DPRC
```

```
RETURN
END
```

```
C SUBROUTINE MINING
      SUBROUTINE MINING
      COMMON /MINEI/ PRC,AO
      COMMON /MINEP/CC,K1,K2,K3,K4
      COMMON /MINES/TM,AIN(20)
      COMMON /GENRLI/ XYZ123(8),AI,XYZ124(102)
      CALL AFNC(TM,CI,K3)
      CALL AFNC(TM,ACM,K1)
      A=PRC/ACM
      CALL AFNC(A,FO,K2)
      AACM=0.
      X=0.
      L=0
  100 CALL AFNC(X,Y,K4)
      AACM=AACM+Y
      X=X+.01
      IF(X.GT.FO) GO TO 150
      L=L+1
      IF(L.LE.99) GO TO 100
  150 AACM=AACM/L
      TI=0.
      DO 200 I=1,20
  200 TI=TI+AIN(I)
      CALL AFNC(TI,Z,56)
      CI=CI/Z
      CLO=TI/CI
      AO=CLO*FO
      GI=AO*PRC
      FM=AO*AACM*ACM
      FC=TI*CC
      P=GI-FM-FC
      IF(TI.LE.0.0) PR=0.0
      IF(TI.GT.0.0) PR=P/TI
      CALL AFNC(PR,RI,11)
      AI=RI*TI
C  UPDATE LEVELS
      TM=TM+AO
      DO 300 I=2,20
      J=20-I+2
  300 AIN(J)=AIN(J-1)
      AIN(1)=AI
      RETURN
      END
```

```
C SUBROUTINE SUPDEM
      SUBROUTINE SUPDEM
      COMMON /SDEMI/ FROUT,ONOUT,CLOUT,OMOUT,AIMP
      COMMON /SDEMP/PMMR,FRMA,BOP
      COMMON /SDEMS/PRROD
      COMMON /GENRLI/ XYZ123,AGOUT,XYZ124(2),OILP,XYZ125(9),OS(10),
     2 XYZ126(84)
      OS(1)=AGOUT
      OS(2)=FROUT
      OS(3)=ONOUT
      OS(4)=CLOUT
      OS(5)=OMOUT
      OS(6)=OMOUT*PMMR
      IF(OILP*FRMA+AIMP.LT.PRROD) GO TO 100
      IF(OILP*FRMA.GT.PRROD) GO TO 200
      OS(7)=PRROD
      GO TO 300
  100 OS(7)=OILP*FRMA+AIMP
      GO TO 300
  200 OS(7)=OILP*FRMA
      PRROD=OILP*FRMA
  300 CONTINUE
      OS(7)=OS(7)*BOP
      RETURN
      END
```

```
C SUBROUTINE DEMAND
      SUBROUTINE DEMAND
      COMMON/DEMNDP/FS,SEXP,FEXP,EPP,RCC,REXC,IRAIL,PED(25),EX(25),
     2  SED(25),FED(25)
      COMMON/GENRLI/XYZ123(6),COAL,XYZ124(2),AVHHI,PT,XYZ128(2),
     1 HT,XYZ125(10),
     2 DM(25),CAP(25),XYZ126(35),FG,SG
      COMMON /DEMNDI/  AVOUT
      COMMON /GENRLP/ KD,XYZ127(2)
      EXPD=AVHHI*HT*FS
      SG=AVOUT*SEXP
      FG=AVOUT*FEXP+PT*EPP
      DO 100 I=1,KD
  100 DM(I)=EXPD*PED(I)*(1.+EX(I))+SG*SED(I)+FG*FED(I)+CAP(I)
      DM(IRAIL)=DM(IRAIL)+COAL*RCC+REXC
      RETURN
      END
```

```
C SUBROUTINE OUTPUT
      SUBROUTINE OUTPUT
      COMMON /OUTPTP/ KS,ADS(25,10),AD(25,25)
      COMMON /GENRLI/ XYZ123(14),OS(10),DM(25),XYZ124(25),OD(35),
     $XYZ126(2)
      COMMON/GENRLP/KD,KT,DT
      COMMON /OUTPTI/ TO
      COMMON/OUTPTS/AVOUT
      DIMENSION A(25)
      DO 110 I=1,KD
      B=0.
      DO 100 J=1,KS
  100 B=B+ADS(I,J)*OS(J)
  110 A(I)=B+DM(I)
      DO 210 I=1,KD
      B=0.
      DO 200 J=1,KD
  200 B=B+AD(I,J)*A(J)
  210 OD(I)=B
      DO 300 I=1,KS
      J=KD+I
  300 OD(J)=OS(I)
      TO=0.
      DO 400 I=1,KT
  400 TO=TO+OD(I)
      AVOUT=AVOUT+(TO-AVOUT)*DT/3
      RETURN
      END
```

```
C SUBROUTINE LABOR
      SUBROUTINE LABOR
      COMMON /LABORI/ TE
      COMMON /LABORP/ WPR,USD,USP,USA,FLH,OER(35),ILB(35),FESR,SESR
      COMMON/LABORS/DW,PW,HAL,AVHHI
      COMMON/GENRLI/ANFRI,XYZ123(9),PT,UEM,WRM,HT,XYZ124(60),OD(35),
     $FGS,SGS
      COMMON /GENRLP/ XYZ125,KT,DT
C EMPLOYMENT
      AE=0
      PE=0
      DE=0
      DO 100 I=1,KT
      IF(ILB(I).EQ.1) AE=AE+OD(I)*OER(I)
      IF(ILB(I).EQ.2) PE=PE+OD(I)*OER(I)
      IF(ILB(I).EQ.3) DE=DE+OD(I)*OER(I)
  100 CONTINUE
C UNEMPLOYMENT AND WAGE CHANGES
      WF=PT*WPR
      PE=PE+FGS*FESR
      DE=DE+SGS*SESR
      TE=AE+PE+DE
      UEM=(WF-TE)/WF
      ED=0.05-UEM
      IF(ED.LT.0.0) ED=0
      DDW=ED*USD*DW
      DPW=ED*USP*PW
      DHAL=ED*USA*HAL
C WAGES
      AWNH=ANFRI/AE/(1.-FLH)
      AW=AWNH*(1.-FLH)+HAL*FLH
      TI=AW*AE+PW*PE+DW*DE
      WRM=TI/TE
      HHI=TI/HT
C UPDATE LEVELS
      DW=DW+DDW*DT
      PW=PW+DPW*DT
      HAL=HAL+DHAL*DT
      AVHHI=AVHHI+(HHI-AVHHI)*DT/3
      RETURN
      END
```

```
C SUBROUTINE CAPINV
      SUBROUTINE CAPINV
      COMMON /CAPINI/ ODS(35)
      COMMON /CAPINP/ATD,DPR(35),CAR(35),IN(35),CPS(25)
      COMMON /CAPINS/RC(35),AO(35)
      COMMON /GENRLI/ XYZ123(2),TI,CFR,XYZ124,TOGI,XYZ125,ACI,AMI,
     2 XYZ126(40),CAP(25),OD(35),XYZ127(2)
      COMMON /GENRLP/ KD,KT,DT
      DIMENSION DAO(35),DIFO(35),DIFR(35),DRC(35),RI(35),DOD(35)
      CP=0
      DO 500 I=1,KT
      C=0
      IF(IN(I).EQ.0) GO TO 500
      DIFO(I)=OD(I)-AO(I)
      IF(ABS(ODS(I)).LT.1000) ODS(I)=1000
      DAO(I)=DIFO(I)/ATD
      DOD(I)=(OD(I)-ODS(I))/(ODS(I)*DT)
      DIFR(I)=DOD(I)-RC(I)
      DRC(I)=DIFR(I)/ATD
      RI(I)=RC(I)+DPR(I)
      IF(RI(I).GT.0) C=AO(I)*RI(I)*CAR(I)
C UPDATE LEVELS
      RC(I)=RC(I)+DRC(I)*DT
      AO(I)=AO(I)+DAO(I)*DT
  500 CP=CP+C
      CP=CP+TI+CFR+TOGI+AMI+ACI
      DO 600 I=1,KD
  600 CAP(I)=CP*CPS(I)
      DO 700 I=1,KT
  700 ODS(I)=OD(I)
      RETURN
      END
```

```
C SUBROUTINE ENRDM
      SUBROUTINE ENRDM
      COMMON /ENRDMI/ ENDEM(5)
      COMMON /ENRDMP/ NENR,NEND,AR(5,10),SAT(5,10),AI(5,35)
      COMMON /GENRLI/ XYZ123(13),HT,XYZ124(60),OD(35),XYZ127(2)
      COMMON /GENRLP/ XYZ125,KT,XYZ126
C    1-- ELECTRICITY--KWH
C     2------GAS------FT**3
C     3----OIL----BTU
C     COAL----4-----BTU
C     5-----OTHER------BTU
      DO 100 I=1,NENR
  100 ENDEM(I)=0
C RESIDENTIAL
      DO 200 I=1,NENR
      DO 200 J=1,NEND
  200 ENDEM(I)=ENDEM(I)+AR(I,J)*SAT(I,J)*HT
C INDUSTRIAL-COMMERCIAL
      DO 300 I=1,NENR
      DO 300 J=1,KT
  300 ENDEM(I)=ENDEM(I)+AI(I,J)*OD(J)
      RETURN
      END
```

```
C SUBROUTINE DEMOG
      SUBROUTINE DEMOG
      COMMON /DEMOGI/ UEN,WRN
      COMMON /DEMOGP/UMC,WMC,IAM1,IAM2,IAF1,IAF2,SMR,MAD,RM(4),AMT(25),
     2AVR(40),DH(30),BH(6,45),IB1,IB2,EHR
      COMMON /DEMOGS/ PC(6,25),PFF(60),PYF(60),PSF(60),PSM(60),PYM(60),
     2  PFM(60),ELD(30)
      COMMON /GENRLI/ XYZ123(10),P,UEM,WRM,HT,XYZ124(94)
      DIMENSION PT(90),PTF(90),PTM(90),BHT(6),HM(6),HRM(4)
C*************************************************************************
      WMC1=WMC
      IF(UEM-UEN.GT.0.02) WMC1=0.0
      A=(1.01+(UEN-UEM)*UMC+((WRM-WRN)/WRN)*WMC1)
      P=P*A
      HT=HT*A
C*************************************************************************
      RETURN
      END
```

```
C SUBROUTINE LAND
      SUBROUTINE LAND
      COMMON /LANDI/ THHC,EMPCO,REFOR,PRESER
      COMMON /LANDP/TONACR,REVEG,CD,EMPACR,RVYRS
      COMMON /LANDS/FL,AGL,UNL,URL,PRL,AML(3)
      COMMON /GENRLI/ XYZ123(6),COALPR,XYZ124(101)
      COMMON /GENRLP/ XYZ125(2),DT
C  COALPR-COAL PRODUCTION(TONS/YR)
C  THHC-NEW HOUSEHOLDS/YR
C  EMPCO-EMPLOYMENT CHANGE(JOBS/YR)
C  REFOR-REFORESTATION(ACRE/YR)
C  PRESER-LAND PRESERVED(ACRE/YR)
C  PRL-PRESERVED LAND(ACRE)
C  FL-FOREST LAND(ACRE)
C AGL-AGRICULTURE LAND
C AML(3)/LAND MINED BEING RECLAIMED(ACRE)3HRD ORDER DELAY
C  UNL-UNUSED LAND(ACRE)
C  URL-URBAN LAND(ACRE)
C  TONACR-TONS CAOL/ACRE
C REVEG-FRACTION OF LAND MINED WHICH CAN BE RECLAIMED
C  CD-HOUSEHOLDS/ACRE
C  EMPACR-EMPLOYEES/ACRE
C  RVYRS-YEARS TO REVEGETATE
C  ACRLOS-ACRES MINED PER YEAR
C  URBLOS-ACRES TO URBAN PER YEAR
C  ACRST-ACRES RECLAIMATION STARTED ON PER YEAR
C  ACRGN-ACRES RECLAIMED PER YEAR
C  UNLOS-ACRES TO UNUSED PER YEAR
      ACRLOS=COALPR/TONACR
      URBLOS=THHC/CD+EMPCO/EMPACR
      UNLOS=ACRLOS*(1.-REVEG)
      ACRST=ACRLOS*REVEG
      ACRGN=AML(3)/(RVYRS*3.)
C  UPDATE LEVELS
      FL=FL+(REFOR-PRESER)*DT
      AGL=AGL+(ACRGN-ACRLOS-URBLOS-REFOR)*DT
      UNL=UNL+UNLOS*DT
      URL=URL+URBLOS*DT
      PRL=PRL+PRESER*DT
      AML(3)=AML(3)+(AML(2)/(RVYRS*3.)-ACRGN)*DT
      AML(2)=AML(2)+(AML(1)/(RVYRS*3.)-AML(2)/(RVYRS*3.))*DT
      AML(1)=AML(1)+(ACRST-AML(1)/(RVYRS*3.))*DT
      RETURN
      END
```

```
C SUBROUTINE HHTCON
      SUBROUTINE HHTCON
      COMMON /HHTCNI/ PRCIN,DHH,AHE
      COMMON /GENRLP/ XYZ123(2),DT
      COMMON /HHTCNP/ BASE,USB,USC,CBO,CCO,CBN,CCN,HRR
      COMMON /HHTCNS/ HSA,HSB,HSC,PRICE
C RESIDENTIAL HEATING ENERGY USE
      PBBA=CBO/(PRICE*BASE*(1.-USB))
      PBCB=(CCO-CBO)/(PRICE*BASE*(USB-USC))
      PBCA=CCO/(PRICE*BASE*(1.-USC))
C
      PBB=CBN/(PRICE*BASE*(1.-USB))
      PBC=CCN/(PRICE*BASE*(1.-USC))
C
      HRC=HSC/HRR
      HRB=HSB/HRR
      HRA=HSA/HRR
      RNH=DHH+HRC+HRB+HRA
C
      CALL AFNC(PBBA,A,57)
      RHABC=HSA*A
      CALL AFNC(PBCA,A,57)
      RHAC=HSA*A
      RHAB=RHABC-RHAC
      CALL AFNC(PBCB,A,57)
      RHBC=HSB*A
C
      CALL AFNC(PBC,FC,58)
      CALL AFNC(PBB,A,58)
      FA=1.-A
      FB=A-FC
      RNHA=RNH*FA
      RNHB=RNH*FB
      RNHC=RNH*FC
C
      CALL AFNC(PRICE,A,59)
      EHHA=BASE*A
      CALL AFNC(PRICE,A,60)
      EHHB=BASE*A*USB
      CALL AFNC(PRICE,A,61)
      EHHC=BASE*A*USC
C
      THE=EHHA*HSA+EHHB*HSB+EHHC*HSC
      THH=HSA+HSB+HSC
      AHE=THE/THH
      HSA=HSA+(RNHA-HRA-RHABC)*DT
      HSB=HSB+(RNHB+RHAB-HRB-RHBC)*DT
      HSC=HSC+(RNHC+RHBC+RHAC-HRC)*DT
      PRICE=PRICE+(PRCIN-PRICE)*DT/2.0
      RETURN
      END
```

```
C SUBROUTINE SUBST
      SUBROUTINE SUBST(X1,X,F,CC,EFFN,EFFO,EFR,TIME)
C SUBSTITUTION IN THE INDUSTRIAL SECTOR
      CALL AFNC(TIME,PRE,65)
      CALL AFNC(TIME,PRS,66)
      SAV=PRE/EFFO-(PRS/EFFN+CC)*EFR
      SAV=SAV/(PRE/EFFO)
      CALL AFNC(SAV,RC,67)
      A=X-X1*(1.-F)
      A=A*(1.-RC)
      X=X1*(1.-F)+A
      RETURN
      END
```

```
C SUBROUTINE AFNC
      SUBROUTINE AFNC(XZ,Y,IZ)
      COMMON /AFNCP/ XFNC(75,30,2),IFNC(75,5)
C   ****************************************************************************
C   REASSIGN THE INPUT ARGUEMENTS
      X=XZ
      I=IZ
C   THIS IS A SUBROUTINE WHICH INTERPOLATES BETWEEN TABLED FUNCTION
C   VALUES BY FITTING A POLYNOMIAL TO A NUMBER OF POINTS
C   X IS THE VALUE OF THE INDEPENDENT VARIABLE
C   Y IS THE VALUE OF THE DEPENDENT VARIABLE CALCULATED
C   I IS THE FUNCTION NUMBER
C   TWO ARRAYS MUST BE SUPPLIED TO IT THROUGH COMMON
C   THE USER MUST SUPPLY A COMMON STATEMENT SUITABLE FOR THE FUNCTIONS
C   BEING USED
C   XFNC(I,J,K) IS THE ARRAY WHICH CONTAINS THE TABLED FUNCTION
C   I IS THE NUMBER OF THE FUNCTION BEING USED
C   J IS THE INDEX FOR FUNCTION POINTS
C   K IS 1 FOR THE INDEPENDENT VARIABLE AND 2 FOR THE DEPENDENT VARIABLE
C   IFNC(I,J) DESCRIBES THE NATURE OF THE FUNCTION
C   I IS THE NUMBER OF THE FUNCTION
C   THE J VALUES ARE USED TO CONVEY INFORMATION ABOUT THE FUNCTION
C   1 STANDS FOR YES, 0 STANDS FOR NO
C   J=1--EXTEND FUNCTION BELOW MINUMUM VALUE OF INDEPENDENT VARIABLE
C   J=2--EXTEND  FU CTION BEYOND MAXIMUM VALUE OF INDEPENDENT VARIABLE
C   J=3--EQUALLY SPACED VALUES OF INDEPENDENT VA IABLE
C   J=4--IS USED FO  THE NUMBER OF DATA POINTS IN THE FUNCTION
C   J=5--IS USED  O  THE NUMBER O  DA   POINT  TO BE USED IN THE IN ERP
C   IERRO  IS A SIGN L USED  O INDICATE A MALFUNCTIO  IN THE IN ERPOLATI
C   0 INDICATES NO ERROR .  1 IN ICAT   AN ER OR
C
C
C   REASSIGN OFTEN U ED AR  Y VALUES
      J4=IFNC(I,4)
      J5=IFNC(I,5)
      X1=XFNC(I,1,1)
      XN=XFNC(I,J4,1)
C   INITIA IZE ER OR PARAMETER
      IERROR=0
C   CHECK TO SEE IF X IS IN THE PROPER RANGE
      IF(X.GE.X1) GO TO 103
      IF(IFNC(I,1).EQ.1) GO TO 102
      WRITE(6,101) I,X
  101 FORMAT(24H BELOW RANGE OF FUNCTION,I4,G15.4)
      IERROR=1
  102 Y=XF NC(I,1,2)
      RETURN
  103 IF(X.LE.XN) GO TO 106
      IF(IFNC(I,2).EQ.1) GO TO 105
      WRITE(6,104) I,X
  104 FORMAT(24H ABOVE RANGE OF FUNCTION,I4,G15.4)
      IERROR=1
  105 Y=XFNC(I,J4,2)
      RETURN
C   FIND STARTING POINT FOR SEARCH FOR INDEPENDENT VARIABLE INDEXES
  106 IX=IFIX(((X-X1)/(XN-X1))*FLOAT(J4-1))+1
```

```
      IF(IX.EQ.J4) IX=J4-1
C   ARE VALUES OF INDEPENDENT VARIABLE EQUALLY SPACED
      IF(IFNC(I,3).EQ.0) GO TO 110
C ARE AN EVEN OR ODD NUMBER OF DATA POINTS TO TO BE USED
 1065 A=FLOAT(J5)*.5
      IA=IFIX(A+.1)
      IF(A.GT.FLOAT(IA)) GO TO 107
      IX=IX-IA+1
      GO TO 150
C   WHICH PART OF INTERVAL IS POINT IN
  107 J=0
      XI1=XFNC(I,IX+1,1)
      IF((XI1-X)/(XI1-XFNC(I,IX,1)).LT.0.5) J=1
      IX=IX-IA+J
      GO TO 150
C   SEARCH FOR INDEXES
  110 J=0
      K=0
  111 IF(X-XFNC(I,IX,1)) 120,120,125
  120 IF(J.EQ.0) GO TO 121
      IX=IX-1
      GO TO 1065
  121 K=1
      IX=IX-1
      IF(IX.NE.0) GO TO 111
      IX=1
      GO TO 1065
  125 IF(K.EQ.1) GO TO 1065
      J=1
      IX=IX+1
      GO TO 111
C   SET INDEXES FOR INTERPOLATION
  150 IF(IX.LT.1) IX=1
      J=J4-J5+1
      IF(IX.GT.J) IX=J
      L=IX+J5-1
C   MAKE INTERPOLATION
      Y=0.
      DO 400 K=IX,L
      YL=1.0
      DO 300 J=IX,L
      IF(J.EQ.K) GO TO 300
      XJ=XFNC(I,J,1)
      YL=YL*(X-XJ)/(XFNC(I,K,1)-XJ)
  300 CONTINUE
  400 Y=Y+YL*XFNC(I,K,2)
      RETURN
      END
```

APPENDIX C

Baseline Case: Data Input and Sample Output

A list of all baseline variables and their definitions is presented in the following table. The variables are listed according to their function and subroutine. After the definition of each variable the proper symbolic name used in the computer program is shown in parenthesis.

Since the model presently contains a simple demographic sub-model the major portion of the demographic variables are not being utilized. Also, in the baseline case, employment/output ratios were held constant after 1972.

SIMULATION CONTROL VARIABLES

TSTRT - Starting data for simulation (yr)
TEND - Ending date for simulation (yr)
DT - Time step (yr)

Scenario Input

ISOER - Employee/output ratios
If ISOER equals 1, use E/O ratios constant after 1972.

ISCON - Residential conservation
If ISCON equals 1, use residential conservation subroutine.

ISPRC - Firm industrial substitution
If ISPRC equals 1, use firm industrial substitutions.

ISPRM - Estrapolated industrial substitution of ISPRM equals 1, use extrapolation.

Print Control

IPRNT	IPRNT2	Computer Printout
1	0	input and output
0	1	output of demands
1	1	input and output of demands
0	0	input/output variables

AGRICULTURAL PARAMETERS

P_1	Price of agricultural land (PL)	\$100.00/(acre)
P_2	Agricultural operating expense/output (OP)	.675
P_3	Agricultural output/labor (OLP)	\$58,500.00/(man/yr)
P_4	Property tax rate (FTR)	.0096-1%
P_5	Agricultural interest rate (RA)	.06-6%
P_6	Fraction of agricultural land mortgaged (PLF)	.06-6%
P_7	Propensity to invest (PTI)	.2
P_8	Fractional loss before disinvestment (TF)	.2
P_9	Salvage value fraction (SALV)	.3
P_{10}	Leverage on cash (ALEVI)	1.0
P_{11}	Agricultural depreciation rate (AKDEP)	.077-7.7%
P_{12}	Capital weighting constant (ALP)	.2
P_{13}	Constant relating Agricultural output to capital & land (A)	10.126

FORESTRY PARAMETERS

P_{14}	Allowed cutting rate (AC)	90.0 (BF/acre/yr)
P_{15}	Capital/cutting rate (FCR)	.053
P_{16}	Depreciation rate forestry (DR)	.067-6.7%
P_{17}	Investment closure time (CT)	5.0 (yrs)

GAS AND OIL PARAMETERS

P_{18}	Gas produced with oil for oil fields (GOR)	400.0 (ft^3/bbl)
P_{19}	Oil produced with gas for gas fields (OGR)	.000010 (bbl/ft^3)
P_{20}	Capital cost for production investment (CCP)	.16 (\$/\$ capital/yr)
P_{21}	Drilling cost (DC)	5.0 (\$/ft)
P_{22}	Gas discovered in oil expenditures (GDOE)	0 (ft^3/bbl)
P_{23}	Oil discovered in gas expenditures (ODGE)	0 (bbl/ft^3)
P_{24}	Exploration investment life (DPT)	5.0 (yr)
P_{25}	Capital cost for exploration (CC)	.3 (\$/\$ capital/yr)
P_{104}	Discount rate	.1

COAL MINING PARAMETERS

P_{26}	Coal mining capital cost (CC)	.16
P_{93}	Price sensitivity to saturation of coal market	.10
P_{94}	Price sensitivity to unsaturation of coal market	.30
P_{103}	Rate new firms enter coal market	.2

COAL MINING PARAMETERS (cont'd)

IP_{27}	Coal mining cost function (K1)	#12
IP_{28}	Coal mining capital function (K2)	#13
IP_{29}	Coal mining cost distribution function (K3)	#14
IP_{96}	Coal cost distribution function	#30

MINING PARAMETERS

P_{30}	Mining capital cost (CC)	.16
IP_{31}	Mining cost function (K1)	#15
IP_{32}	Mining capital function (K2)	#16
IP_{33}	Mining cost distribution function (K3)	#17
IP_{97}	Mine cost distribution function	#31

SUPPLY AND DEMAND PARAMETERS

P_{34}	Primary metals output/mining output (PMMR)	2.48
P_{35}	Fraction of oil available for mining (FRMA)	.29
P_{36}	Base oil price (BOP)	$4.00/bbl

DEMAND PARAMETERS

P_{37}	Fraction of earned income spent	.715-71.5%
P_{38}	State government expenditures/household expenditures (RGPES)	.1215
P_{39}	Federal government expenditures/household expenditures (RGPEF)	.1013
P_{40}	Rail cost/ton (RCC)	$.01/(ton/mile)
P_{41}	Rail export constant (REXC)	$100,000,000
P_{102}	Federal government expenditures/person	$786.00
IP_{42}	Rail sector index (IRAIL)	11
IP_{43}	No. of supply controlled sectors (KS)	23
PA_{66}	Household expenditure vector (PED[25])	

0.0	.03457	.01938	.00413	.03211	.00276
.00477	.00044	.00108	.04046	.00446	.01632
.01597	.02840	.04275	.16852	.18643	.04549
.01041	.06142	.00113	.00110	.00262	0.0
0.0					

PA_{67} Exports/household expenditure vector (EX[25])

0.0	.57493	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
.41430	.73936	0.0	.62587	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

PA_{68} State government expenditure vector (SED[25])

.22178	.00202	.00093	.00010	.00115	.00321
.00217	.00009	.00070	.00877	.00073	.00907
.00545	.01810	.00634	-.00371	.01100	.00123
.00834	.02711	.00118	.00015	.01304	0.0
0.0					

PA_{69} Federal government expenditure vector (FED[25])

.04042	.00140	.00387	.00042	.00066	.00083
.00659	.00123	.00046	.10503	.00420	.02819
.00599	.00379	.01228	-.00024	.00363	.01169
.01306	.02058	.00140	.00184	-.00141	0.0
0.0					

OUTPUT PARAMETERS

IP_{44} Number of demand sectors 7

PA_{70} Direct coefficients supply output-demand (ADS[25,10])

.00652	.00435	.02582	.00549	.00749	.00434
.01121	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
.00005	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
.02365	0.0	0.0	0.0	0.0	.00117
0.0	0.0	0.0	0.0	0.0	0.0
.00314	.00001	0.0	0.0	0.0	0.0
.00062	0.0	0.0	0.0	0.0	0.0
.00007	.00004	.00001	.00001	.00004	.00002
.00004	0.0	0.0	0.0	0.0	0.0
.01444	.00382	.00282	.00473	.01078	.00595
.00832	0.0	0.0	0.0	0.0	0.0
.00023	.00297	.00142	.00312	.00068	.00015
.00071	0.0	0.0	0.0	0.0	0.0
.00051	.00642	.00568	.00324	.00250	.00158
.00015	0.0	0.0	0.0	0.0	0.0
.00287	.00643	.01093	.01760	.02012	.00418
.00296	0.0	0.0	0.0	0.0	0.0
.00543	.01740	.00169	.00500	.00648	.01910
.00161	0.0	0.0	0.0	0.0	0.0
.00935	.00720	.00170	.00319	.00315	.00622
.04367	0.0	0.0	0.0	0.0	0.0
.00237	.00276	.00090	.00161	.00769	.00142
.00085	0.0	0.0	0.0	0.0	0.0
.00645	.01176	.01043	.02175	.03140	.05076
.01826	0.0	0.0	0.0	0.0	0.0
.01977	.02388	.00442	.01553	.01066	.01553
.00612	0.0	0.0	0.0	0.0	0.0
.01485	.00232	.00395	.00171	.00308	.00065
.00039	0.0	0.0	0.0	0.0	0.0
.05611	.01570	.17407	.05778	.04581	.01010

PA70 Direct coefficients supply output-demand (ADS[25]) cont'd

.03410	0.0	0.0	0.0	0.0	0.0
.00038	.00031	.00030	.00049	.00079	.00026
.00060	0.0	0.0	0.0	0.0	0.0
.01168	.01069	.00549	.01304	.01099	.00531
.01677	0.0	0.0	0.0	0.0	0.0
.00266	.00226	.00759	.00332	.00461	.00183
.00099	0.0	0.0	0.0	0.0	0.0
.00003	.00030	.00021	.00030	.00048	.00012
.00029	0.0	0.0	0.0	0.0	0.0
.00002	.00013	0.0	0.0	0.0	.00014
.00001	0.0	0.0	0.0	0.0	0.0
.00091	.00309	.01303	.00383	.00872	.01718
.00179	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

PA_{71} Net coefficients demand sectors (AD[25,25])

0.1003E 01	0.2390E-02	0.3959E-02	0.6247E-02	0.5327E-02	0.6368E-02
0.1079E-01	0.4678E-02	0.1704E-01	0.7012E-02	0.7051E-01	0.6432E-02
0.2065E-01	0.3643E-01	0.3669E-02	0.5965E-02	0.1412E-01	0.2129E-01
0.7417E-02	0.1076E-01	0.1157E-01	0.1381E 00	0.9772E-02	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.1635E-02	0.1128E 01	0.1071E-02	0.3150E-02	0.1038E-01	0.2570E-02
0.2332E-02	0.2004E-02	0.1423E-02	0.5715E-02	0.1064E-02	0.2602E-02
0.2174E-02	0.9752E-03	0.4203E-02	0.1133E-02	0.3582E-02	0.3786E-02
0.2466E-02	0.1052E-01	0.1073E-02	0.1400E-02	0.1141E 00	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.4150E-03	0.8322E-03	0.1185E 01	0.9229E-02	0.6624E-02	0.5670E-03
0.5019E-03	0.4238E-03	0.3141E-03	0.7969E-03	0.2291E-03	0.6407E-03
0.5129E-03	0.2225E-03	0.9337E-03	0.2780E-03	0.8730E-03	0.1900E-02
0.5610E-03	0.5151E-02	0.5353E-02	0.3220E-03	0.2312E-01	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.2622E-03	0.1036E-03	0.2320E-02	0.1118E 01	0.5645E-01	0.6387E-03
0.4778E-03	0.2084E-03	0.2023E-03	0.8513E-02	0.1521E-03	0.2046E-03
0.2037E-03	0.8264E-04	0.2385E-03	0.1697E-03	0.2686E-03	0.1512E-02
0.4293E-03	0.1175E-02	0.5715E-02	0.1358E-03	0.4112E-02	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.5922E-03	0.1228E-02	0.9769E-02	0.7813E-01	0.1110E 01	0.8653E-03
0.3975E-02	0.6594E-03	0.4976E-03	0.1794E-02	0.3830E-03	0.9729E-03
0.7306E-03	0.3262E-03	0.1375E-02	0.5238E-03	0.1217E-02	0.1894E-02
0.8309E-03	0.5129E-02	0.3441E-02	0.4837E-03	0.3584E-01	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.3498E-03	0.2312E-02	0.1148E-02	0.6993E-03	0.2957E-02	0.1016E 01
0.4739E-03	0.3751E-03	0.5027E-03	0.4688E-03	0.1017E-02	0.7178E-03
0.1110E-02	0.2998E-03	0.1017E-02	0.1029E-02	0.4812E-02	0.4577E-02

PA_{71} Net coefficients demand sectors (AD[25,25]) cont'd

0.7015E-03	0.2187E-02	0.1618E-02	0.1259E-02	0.9072E-02	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.5693E-02	0.2683E-02	0.1275E-02	0.8106E-02	0.2937E-02	0.6225E-02
0.1077E 01	0.4903E-02	0.4715E-02	0.1563E-01	0.2121E-02	0.7944E-03
0.6010E-03	0.9411E-03	0.6198E-03	0.6717E-03	0.8033E-03	0.5258E-02
0.3244E-02	0.1108E-01	0.1365E-02	0.5827E-02	0.2206E-02	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.1967E-01	0.1622E-02	0.3433E-02	0.2653E-02	0.4850E-02	0.1100E-02
0.2098E-01	0.1011E 01	0.2289E-02	0.6383E-02	0.2541E-02	0.7112E-03
0.6982E-03	0.1031E-02	0.5292E-03	0.8126E-03	0.8259E-03	0.1649E-02
0.3655E-02	0.7830E-03	0.6866E-03	0.3280E-02	0.1386E-02	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.7518E-01	0.5914E-03	0.2015E-02	0.2129E-02	0.1674E-01	0.1262E-02
0.5101E-02	0.7793E-02	0.1145E 01	0.5889E-02	0.6349E-02	0.1919E-02
0.1945E-02	0.2891E-02	0.1834E-02	0.2080E-02	0.1827E-02	0.4081E-02
0.9807E-02	0.7079E-02	0.1443E-02	0.1139E-01	0.2520E-02	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.2246E-01	0.3150E-02	0.2310E-01	0.1305E-01	0.1641E-01	0.6443E-01
0.1479E-01	0.1591E-01	0.1745E-01	0.1054E 01	0.1237E-01	0.1134E-01
0.7794E-02	0.3942E-02	0.7606E-02	0.7158E-02	0.6128E-02	0.1871E-01
0.3731E-01	0.1180E-01	0.5692E-02	0.8673E-02	0.2983E-01	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.1318E-01	0.4119E-02	0.4067E-02	0.3012E-01	0.4695E-02	0.1012E-01
0.2032E-01	0.1053E-01	0.3434E-01	0.1703E-01	0.1060E 01	0.8942E-02
0.2471E-02	0.1836E-01	0.2975E-02	0.1889E-02	0.3270E-02	0.1617E-01
0.5684E-02	0.3319E-02	0.5705E-01	0.9259E-02	0.4429E-01	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.2464E-01	0.2854E-01	0.8276E-02	0.3520E-01	0.2524E-01	0.1466E-01
0.1978E-01	0.1533E-01	0.6055E-01	0.2189E-01	0.1677E-01	0.1111E 01
0.9307E-02	0.1016E-01	0.2746E-01	0.5890E-02	0.1327E-01	0.3717E-01
0.1514E-01	0.1398E-01	0.9638E-01	0.1529E-01	0.2981E 00	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.6560E-02	0.3034E-02	0.9040E-02	0.5500E-02	0.8609E-02	0.1980E-01
0.7161E-02	0.8462E-02	0.9033E-02	0.8251E-02	0.1132E-01	0.1551E-01
0.1020E 01	0.5354E-02	0.2009E-01	0.1078E-01	0.2247E-01	0.1652E-01
0.1650E-01	0.1342E-01	0.6053E-02	0.7674E-02	0.9909E-02	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.9580E-02	0.1016E-01	0.1552E-01	0.1836E-01	0.1375E-01	0.1218E-01
0.4991E-01	0.1435E-01	0.6467E-01	0.2385E-01	0.1538E-01	0.1050E-01
0.1477E-01	0.1282E 01	0.1213E-01	0.3018E-01	0.2102E-01	0.5270E-01
0.1046E-01	0.3986E-01	0.2532E-01	0.1543E 00	0.1939E-01	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.3566E-01	0.1920E-01	0.3741E-01	0.5406E-01	0.3224E-01	0.2156E-01
0.2285E-01	0.2260E-01	0.2287E-01	0.3096E-01	0.1333E-01	0.3297E-01
0.6371E-02	0.7188E-02	0.1019E 01	0.8436E-02	0.8977E-02	0.1946E-01
0.3342E-01	0.1594E-01	0.1238E-01	0.1494E-01	0.1822E-01	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.4471E-01	0.2500E-02	0.5310E-02	0.5154E-02	0.5331E-02	0.9591E-02
0.7468E-02	0.1049E-01	0.6878E-02	0.1071E-01	0.6060E-02	0.1864E-01
0.9368E-02	0.5229E-02	0.2308E-01	0.1006E 01	0.1186E-01	0.1546E-01
0.2322E-01	0.1426E-01	0.5285E-02	0.1042E-01	0.1112E 00	0.0

PA_{71} Net coefficients demand sectors (AD[25,25]) cont'd

0.0	0.0	0.0	0.0	0.0	0.0
0.3083E-01	0.1370E-01	0.2607E-01	0.2566E-01	0.5854E-01	0.5282E-01
0.4974E-01	0.3230E-01	0.5192E-01	0.2890E-01	0.7792E-01	0.5361E-01
0.4388E-01	0.2226E-01	0.7470E-01	0.9611E-01	0.1201E 01	0.1372E 00
0.7078E-01	0.7304E-01	0.5256E-01	0.5051E-01	0.5901E-01	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.4556E-02	0.2684E-02	0.6755E-02	0.4230E-02	0.4958E-02	0.9351E-02
0.6637E-02	0.8089E-02	0.4813E-02	0.8658E-02	0.4568E-02	0.5233E-02
0.4818E-01	0.4357E-02	0.1138E-01	0.8865E-02	0.1403E-01	0.1050E 01
0.9288E-02	0.1334E-01	0.3653E-02	0.4263E-02	0.2183E 00	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.1895E-01	0.8768E-02	0.2321E-01	0.3100E-01	0.2958E-01	0.3442E-01
0.2461E-01	0.1423E-01	0.2297E-01	0.1846E-01	0.1221E-01	0.3135E-01
0.2437E-01	0.8741E-02	0.4299E-01	0.3076E-01	0.5747E-01	0.3774E-01
0.1019E 01	0.1762E-01	0.2336E-01	0.2609E-01	0.2220E-01	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.2876E-01	0.1898E-02	0.4971E-02	0.3908E-02	0.5630E-02	0.1342E-01
0.7200E-02	0.4597E-02	0.6613E-02	0.6121E-02	0.7442E-02	0.5672E-02
0.5971E-02	0.4211E-02	0.2252E-01	0.8246E-02	0.2604E-01	0.1614E-01
0.1285E-01	0.1027E 01	0.3640E-02	0.1052E-01	0.6539E-02	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.1807E-02	0.1029E-02	0.2422E-02	0.1864E-02	0.2442E-02	0.6864E-02
0.2653E-02	0.2609E-02	0.2239E-02	0.2898E-02	0.2701E-02	0.2635E-02
0.1207E-01	0.3077E-02	0.5098E-02	0.5500E-02	0.1567E-01	0.2149E 00
0.8288E-02	0.5856E-02	0.1001E 01	0.2489E-02	0.4565E-01	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.3099E-03	0.2022E-03	0.2761E-03	0.2157E-03	0.2394E-03	0.1627E-03
0.3582E-03	0.9121E-04	0.2186E-03	0.2304E-03	0.2141E-03	0.2255E-02
0.3048E-03	0.1380E-03	0.6224E-03	0.3615E-03	0.3325E-03	0.8468E-03
0.2787E-03	0.5975E-03	0.3436E-03	0.1000E 01	0.8347E-03	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.1204E-01	0.4230E-02	0.7979E-02	0.8862E-02	0.8680E-02	0.2064E-01
0.1741E-01	0.1709E-01	0.1130E-01	0.3018E-01	0.7854E-02	0.1194E-01
0.1875E-01	0.8233E-02	0.3559E-01	0.9367E-02	0.3000E-01	0.3190E-01
0.2028E-01	0.2778E-01	0.8008E-02	0.1147E-01	0.1012E 01	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

LABOR PARAMETERS

P_{45}	Labor/population (WPR)	.4
P_{46}	Derivative wages sensitivity (USD)	1.0
P_{47}	Primary wage sensitivity (USP)	1.0
P_{48}	Hired agriculutral wages (USA)	1.0
P_{49}	Fraction of farm labor hired (FLH)	.3
IP_{50}	Total number of sectors (KT)	30
PA_{72}	Employment/out	

.000033	.000016	.000016	.000016	.000016	.000028
.000028	.000028	.000028	.000028	.000037	.000038
.000032	.000014	.000078	.000078	.000017	.000118
.000118	.000118	0.0	0.0	.000118	.0000407
.000030	.000014	.000011	.000025	.000009	.000005

IPA_{73} Sector employment types (ILB[35])

1-agricultural
2-primary employment
3-derivative employment

3	2	2	2	2	2	2	2	2	2	2	3
3	3	3	3	3	3	3	3	2	3	3	1
2	2	2	2	2	2						

CAPITAL INVESTMENT PARAMETERS

P_{51}	Delay times (ATD)	5.0 (yrs)
PA_{74}	Sector depreciation rates (DPR[35])	

.093	.065	.065	.065	.065	.066
.067	.082	.082	.082	.038	.038
.033	.033	.052	.052	.047	.097
.097	.097	.097	.097	.097	.065
.065	.067	.067	.067	.082	.067
0.0					

PA_{75} Sector capital-output ratios (CAR[35])

.19	.25	.25	.25	.25	.39
.5	.59	.59	.59	1.76	1.763
3.	3.	.65	.65	1.05	.95
.95	.95	.95	.95	.95	.25
.25	.5	.5	.5	.59	.5
0.0					

IPA_{76} Investment calculation index (IN[35])

1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	0
0	0	0	0	1	1						

PA_{90} Capital expenditure vector (CPS[25])

.55070	0.0	0.0	0.0	0.0	0.0
0.0	.00082	0.0	.03365	.01502	.00810
.01408	.03002	.05412	.05400	.00591	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

ENERGY DEMAND PARAMETERS

IP_{52} No. of energy types (NENR) (electricity, natural gas, oil, coal) 4

IP_{53} No. of end uses (space heating, kitchen range, refrigerator, freezer, clothes dryer, air conditioner, other) 8

PA_{77} Appliance energy use (AR[r,10])

27400.	4220.	1180.	1140.	1200.	990.
460.	740.	0.0	0.0	93800.	16300.
6420.	0.0	0.0	3250.	0.0	0.0
0.0	0.0	141300000.	26500000.	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
161900000.	88300000.	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	93800000.	16300000.
6420000.	0.0	0.0	3250000.	0.0	0.0
0.0					

PA_{78} Appliance saturations (SAT[5,10])

.023	.179	.782	1.051	.653	.688
.134	1.	0.0	0.0	.833	.787
.193	0.0	0.0	.039	0.0	1.
0.0	0.0	.071	0.0	0.0	0.0
0.0	0.0	0.0	1.	0.0	0.0
.019	0.0	0.0	0.0	0.0	0.0
0.0	1.	0.0	0.0	.049	.029
.023	0.0	0.0	.003	0.0	1.
0.0					

PA_{79} Energy coefficients (AI[5,35])

.859	.270	.270	.270	.270	.199
19.911	.0417	.927	.0068	.129	0.0
.859	0.0	.859	.859	.859	.859
.859	.859	.859	.859	.859	.840
1.292	.786	.0768	.137	8.708	1.335
0.0	0.0	0.0	0.0	0.0	6.76
13.55	13.55	13.55	13.55	15.7	44.7
31.4	103.8	6.02	0.0	0.0	6.76
5.22	6.76	6.76	6.76	6.76	6.76

PA_{79} Energy coefficients (AI[5,35]) cont'd

6.76	6.76	6.76	6.76	0.0	18.73
0.0	6.48	6.48	29.8	19.18	0.0
0.0	0.0	0.0	0.0	4872.	7006.
7006.	7006.	7006.	7006.	7006.	7006.
7006.	7006.	60131.	60131.	4872.	1098.
4872.	4872.	4872.	4872.	4872.	4872.
4872.	4872.	4872.	31292.	7006.	7006.
7006.	7006.	7006.	7006.	0.0	0.0
0.0	0.0	0.0	1230.	2340.	2340.
2340.	2340.	2340.	2340.	2340.	2340.
2340.	2340.	2340.	1230.	53440.	1230.
1230.	1230.	1230.	1230.	1230.	1230.
1230.	1230.	0.0	2340.	2340.	2340.
2340.	2340.	2340.	0.0	0.0	0.0
0.0	0.0	1466.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	1466.	0.0	1466.	1466.
1466.	1466.	1466.	1466.	1466.	1466.
1466.	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

DEMOGRAPHY PARAMETERS

P_{54}	Unemployment migration constant (UMC)	.3
P_{55}	Wage migration constant (WMC)	.5
IP_{56}	Age children begin leaving home (IAM1)	15
IP_{57}	Age all children have left home (IAM2)	24
IP_{58}	Age family formation starts (IAF1)	16
IP_{59}	Age family formation ends (IAF2)	36
P_{60}	Single family females/married females (SMR)	.086
IP_{61}	Marrying age difference between females & males (MAD)	2 (yrs)

PA_{80} Relative age mobilities (RM[4])

1.0	1.0	.6	.3

PA_{81} Maturation rates (AMT[25])

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	.05	.10	.25
.40	.55	.65	.75	.85	.95
1.00					

PA_{82} Marriage rates (AMR[40])

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	.039	.078	.117
.156	.135	.105	.075	.045	.020
.015	.015	.015	.015	.015	.0035
.0035	.0035	.0035	.0035	0.0	0.0
0.0	0.0	0.0	0.0		

PA_{83} Death rates (DH[30])

0.0	.034	.069	.103	.138	.172
.206	.241	.275	.310	.344	.378
.413	.241	.275	.310	.344	.378
.619	.654	.688	.722	.757	.791
.826	.860	.894	.929	.963	1.0

PA_{84} Birth rates (BH[6,45])

0.0					
0.0					
0.0					
0.0					
0.0					
0.0					
0.0					
0.0					
0.0					
0.0					
0.0					
0.0					
0.0					
0.0					
0.0					
.0233	0.0	0.0	0.0		
.0466	.0103	0.0	0.0		
.0699	.0206	0.0	0.0		
.0932	.0309	.0048	0.0		
.1164	.0413	.0097	0.0		
.1050	.0516	.0145	.0022		
.0815	.0575	.0242	.0007	.0018	.0005
.0699	.0531	.0291	.0090	.0026	.0010
.0582	.0486	.0339	.0112	.0035	.0014
.0466	.0442	.0317	.0134	.0044	.0019
.0349	.0398	.0274	.0157	.0053	.0024
.0233	.0354	.0271	.0148	.0061	.0029
.0116	.0309	.0249	.0139	.0070	.0033
0.0	.0265	.0226	.0130	.0079	.0038
0.0	.0221	.0204	.0122	.0074	.0035
0.0	.0177	.0181	.0133	.0068	.0033
0.0	.0133	.0158	.0105	.0063	.0030
0.0	.0088	.0136	.0096	.0058	.0028
0.0	.0044	.0113	.0087	.0053	.0025

PA_{84} Birth rates (BH[6,45]) cont'd

0.0	.0090	.0078	.0047	.0023
0.0	.0068	.0070	.0042	.0020
0.0	.0045	.0061	.0037	.0018
0.0	.0023	.0052	.0032	.0015
0.0	0.0	.0044	.0026	.0013
0.0	0.0	.0035	.0021	.0010
0.0	0.0	.0026	.0016	.0008
0.0	0.0	.0017	.0011	.0005
0.0	0.0	.0009	.0005	.0003
0.0	0.0	0.0	0.0	0.0
0.0				

IP_{91}	Age females start giving birth (IB1)	16
IP_{92}	Age females stop giving birth (IB2)	45
P_{95}	Number of households per elderly person	.7

LAND USE PARAMETERS

P_{62}	Tons of coal mined/acre (TONACR)	28320 (tons/acre)
P_{63}	Fraction of strip-mined land revegetated (REVEG)	.8-80%
P_{64}	No. of households/acre (CD)	.354 (h/acre)
P_{65}	No. of years to revegetate	10 (yrs)
P_{85}	No. of employees/acre (EMPACR)	1.3 (emp/acre)

HOUSEHOLD CONSERVATION PARAMETERS

P_{106}	Energy use in an average home heated with no insulation (BASE)	135840. (ft^3)
P_{107}	Fraction of energy use in a class "B" insulated home (USB)	.74
P_{108}	Fraction of energy use in a class "C" insulated home (USC)	.315
P_{109}	Cost of insulating an existing home to class "B" standards (CBO)	$360
P_{110}	Cost of insulating an existing home to class "C" standards (CCO)	$2,470.
P_{111}	Cost of insulating a new house to class "B" standards (CBN)	$300.
P_{112}	Cost of insulating a new house to class "C" standards (CCN)	$1,970.
P_{113}	Life span of an average house (HRR)	75 (yrs)

OTHER PARAMETERS

P_{86}	Forestry output/timber cut	.2
P_{87}	Base-gas price	.003 ($/$ft^3$)

OTHER PARAMETERS (cont'd)

P_{88}	Base coal price	3.4 ($/ton)
P_{89}	Base mining product price	1.0 ($/ton)

AGRICULTURAL STATE VARIABLES

S_{15}	Owned agricultural capital (AKO)	$210,000,000
S_{16}	Financed agricultural capital (AKF)	$210,000,000

FORESTRY STATE VARIABLES

S_{17}	Timber allowed to cut (TAC)	1,500,000,000 (BF/yr)
S_{18}	Forestry capital investments (CAP)	$80,000,000

GAS AND OIL STATE VARIABLES

S_{19}	Abandoned oil fields (AFO)	0
S_{20}	Abondoned gas fields (AFG)	0
S_{21}	Exploration investment for oil (ODI)	$10,000,000
S_{22}	Exploration investment for gas (GDI)	$5,000,000
S_1	Producing oil Fields (PRO[50])	

20,000,000	0.0	30,000,000	0.0	40,000,000	0.0
50,000,000	0.0	90,000,000	0.0	100,000,000	0.0
100,000,000	0.0	125,000,000	0.0	125,000,000	0.0
125,000,000	0.0	125,000,000	0.0	125,000,000	0.0
100,000,000	0.0	95,000,000	0.0	90,000,000	0.0
85,000,000	0.0	80,000,000	0.0	75,000,000	0.0
70,000,000	0.0	65,000,000	0.0	60,000,000	0.0
55,000,000	0.0				

S_2 Producing gas fields (PRG[50])

80,000,000,000	0.0	100,000,000,000	0.0	130,000,000,000	0.0
130,000,000,000	0.0	150,000,000,000	0.0	150,000,000,000	0.0
150,000,000,000	0.0	150,000,000,000	0.0	130,000,000,000	0.0
120,000,000,000	0.0	90,000,000,000	0.0	80,000,000,000	0.0
70,000,000,000	0.0	60,000,000,000	0.0	50,000,000,000	0.0
40,000,000,000	0.0	30,000,000,000	0.0	30,000,000,000	0.0
25,000,000,000	0.0	25,000,000,000	0.0	20,000,000,000	0.0
20,000,000,000	0.0	20,000,000,000	0.0	15,000,000,000	0.0
15,000,000,000	0.0				

COAL MINING STATE VARIABLES

S_{23}	Total coal mined (TM)	0.0 (tons)
S_{37}	Actual coal price (PRC)	3.4 ($/ton)

S_5 Coal investment (AlN[20])

3,150,000	3,050,000	2,940,000	2,840,000	2,730,000	2,630,000
2,520,000	2,420,000	2,310,000	2,210,000	2,100,000	1,990,000
1,890,000	1,780,000	1,680,000	1,580,000	1,470,000	1,360,000
1,260,000	1,150,000				

MINING STATE VARIABLES

S_{24} Total mined (TM) 0.0(tons)
S_6 Mining investment (AlN[20])

30,000,000	29,000,000	28,000,000	27,000,000	26,000,000	0.0
24,000,000	23,000,000	22,000,000	21,000,000	20,000,000	0.0
18,000,000	17,000,000	16,000,000	15,000,000	14,000,000	0.0
12,000,000	11,000,000				

SUPPLY AND DEMAND VARIABLES

S_{25} Oil refinery capacity (PRROD) 59,000,000 (bbl/yr)

OUTPUT STATE VARIABLES

S_{38} Average output for Montana (AVOUT) \$5,390,000,000

LABOR STATE VARIABLES

S_{26}	Derivative wage rate (DW)	5,072.00 (\$/yr)
S_{27}	Primary wage rate (PW)	9,480.00 (\$/yr)
S_{28}	Hired agricultural wage rate (HAL)	3,340.00 (\$/yr)
S_{39}	Average household income (AVHHI)	10,500.00 (\$/yr)

CAPITAL INVESTMENT STATE VARIABLES

S_{34} Averaged rate of change (RC[35])

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

S_{35} Averaged outputs for each sector (AO[35])

1.	Construction	398,000,000	6.	Print & Publish	32,000,000
2.	Meat Process	106,000,000	7.	Chemical	25,000,000
3.	Dairy Process	44,000,000	8.	Fabricated Metals	14,000,000
4.	Grain Process	40,000,000	9.	Stone & Clay	42,000,000
5.	Other Food	67,000,000	10.	Other Manufacturing	225,000,000

S_{35} Averaged outputs for each sector (AO[35]) cont'd

11.	Railroad Transportation	179,000,000	21.	Federal Enterprizes	18,000,000
12.	Motor Freight	135,000,000	22.	State & Local Enterprizes	29,000,000
13.	Communications	108,000,000	23.	Dummy	39,000,000
14.	Utility	213,000,000	24.	Agricultural	931,000,000
15.	Wholesale	173,000,000	25.	Forestry	299,000,000
16.	Retail Trade	513,000,000	26.	Petroleum & Natural Gas	108,000,000
17.	Finance, Insurance, & Real Estate	533,000,000	27.	Coal Mining	17,000,000
18.	Personal Service	119,000,000	28.	Non-Energy Mining	177,000,000
19.	Business Repair	86,000,000	29.	Primary Metals	440,000,000
20.	Professional Services	185,000,000	30.	Petroleum Refining	233,000,000

DEMOGRAPHY STATE VARIABLES

S_7 I^{th} child at age J (PC[6,25])

4683.	3278.	1756.	1054.	468.	234.
4488.	3142.	1908.	1010.	449.	224.
4336.	3035.	1843.	976.	434.	217.
4577.	3204.	1945.	1030.	458.	229.
4746.	3322.	2017.	1068.	475.	237.
5196.	3637.	2208.	1169.	520.	260.
5592.	3914.	2377.	1258.	559.	280.
5926.	4149.	2519.	1333.	593.	296.
6007.	4205.	2553.	1352.	601.	300.
6182.	4327.	2627.	1319.	618.	309.
6486.	4260.	2587.	1369.	609.	304.
6182.	4327.	2627.	1319.	618.	309.
6381.	4467.	2712.	1436.	638.	319.
6221.	4355.	2644.	1400.	622.	311.
6177.	4324.	2625.	1390.	618.	309.
6172.	4320.	2623.	1389.	617.	308.
5698.	3988.	2421.	1282.	570.	285.
5082.	3557.	2160.	1143.	508.	254.
3449.	2414.	1466.	776.	345.	173.
1822.	1275.	774.	410.	182.	91.
768.	538.	326.	173.	77.	39.
262.	184.	112.	59.	26.	13.
87.	61.	37.	20.	9.	5.
8.	6.	3.	2.	1.	.5
0	0	0	0	0	0

S_8 Number of married females age J (PFF[60])

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	38.	962.
1683.	2473.	3251.	3740.	4205.	4159.
3417.	3705.	3759.	4023.	3608.	3635.

S_8 Number of married females age J (PFF@60]) cont'd

3686.	3467.	3418.	3525.	3418.	3486.
3210.	3315.	3400.	3466.	3775.	3583.
3602.	3502.	3550.	3528.	3612.	3547.
3786.	3505.	3838.	3737.	3633.	3591.
3420.	3448.	3311.	3224.	3146.	3019.

S_9 Number of young single females age J (PYF[60])

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	72.
742.	1089.	1437.	1399.	1140.	937.
669.	614.	567.	494.	395.	303.
307.	288.	241.	249.	241.	247.
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

S_{10} Number of mature single females age J (PSF[60])

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
242.	250.	216.	261.	284.	270.
271.	264.	267.	166.	272.	267.
285.	264.	289.	381.	273.	270.
257.	260.	249.	243.	237.	227.

S_{11} Number of mature single males age J (PSM[60])

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
483.	499.	512.	522.	568.	539.
542.	527.	534.	531.	544.	534.
570.	532.	578.	563.	547.	541.
515.	519.	498.	485.	474.	454.

S_{12} Number of young single males age J (PYM[60])

0	0	0	0	0	
0	0	0	0	0	
0	0	0	0	36.	148.
875.	1285.	1694.	1965.	1473.	1266.

S_{12} Number of young single males age J (PYM[60]) cont'd

940.	907.	865.	813.	681.	591.
599.	563.	512.	528.	512.	523.
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

S_{13} Number of married males age J (PFM[60])

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	2.	886.
1550.	227.	2994.	34444.	3872.	3830.
3146.	3412.	3461.	3704.	3322.	3347.
3394.	3192.	3147.	3246.	3147.	3210.
2969.	3066.	3144.	3205.	3491.	3314.
3331.	3239.	3783.	3263.	3340.	3280.
3501.	3237.	3549.	3455.	3359.	3320.
3162.	3189.	3062.	2982.	2909.	2792.

S_{14} Number of elderly age J (ELD[30])

6538.	5810.	5772.	5265.	5050.	4940.
4752.	4374.	3886.	4076.	3850.	3399.
3207.	3207.	3135.	3089.	2963.	2851.
2654.	2323.	2198.	1911.	1692.	1524.
885.	885.	885.	885.	885.	253.

LAND USE STATE VARIABLES

S_{29}	Forest land (FL)	16,660,000	(acres)
S_{30}	Agricultural land (AGL)	62,900,000	(acres)
S_{31}	Waste land (UNL)	10,562,000	(acres)
S_{32}	Urban land (URL)	818,000	(acres)
S_{33}	Wilderness land (PRL)	2,145,000	(acres)
S_{36}	Mined land (third order delay) (AML[3])		

1,333.3 1,333.3 1,333.3

HOUSEHOLD CONSERVATION STATE VARIABLES

S_{40}	65100.
S_{41}	86800.
S_{42}	65100.
S_{43}	.0000014

MISCELLANEOUS VARIABLES

AI_3 Demands from capital investment (CAP[25])

.000156	0.0	0.0	0.0	0.0	0.0
	.00000023		.0000095	.0000043	.0000023
.000004		.0000085	.0000153	.0000017	
0.0					
0.0					

AI_6 Lagged outputs for each sector (ODS[35])

398000000.	106000000.	44000000.	40000000.	67000000.	32000000.
25000000.	14000000.	42000000.	255000000.	179000000.	135000000.
108000000.	213000000.	173000000.	513000000.	533000000.	119000000.
86000000.	185000000.	18000000.	29000000.	39000000.	931000000
299000000.	108000000.	17000000.	177000000.	440000000.	233000000.

A_{26}	Earned income (AIN) or (TI)	$2,400,000,000.00
A_{27}	Total Montana population (PT)	694,000
A_{30}	Total Montana households	217,000
A_{40}	Limit on tons of coal mined per year	300,000,000 (tons)
V_1	Previous total employment	265,700
V_2	Previous total households	217,000

FUNCTIONS

The following functions are used as a means to interpolate between given points. AFNC (X,Y,Z) is the notation used in the program where X is the value of the independent variable, Y is the value of the dependent variable calculated and Z is the function number.

AFNC (TIME, A_2,20) - Price of agricultural products (P)

1	1	1	6	3	
70.	1972.	1974.	1976.	1978.	1980.
	1.	1.5	1.3	1.3	1.3

AFNC (TIME, A_{10},21) - Oil price (OP)

1	1	1	7	3	
70.	1975.	1980.	1985.	1990.	1995.
00.	4.0	7.0	10.0	11.0	12.0
.0	20.0				

AFNC (TIME, A_{11},22) - Gas price (GP)

1	1	1	7	3	
70.	1975.	1980.	1985.	1990.	1995.
00.	.0002	.0004	.001	.002	.003
04	.035				

AFNC (TIME, A_{15},23) - Coal price (PRC)

1	1	1	7	3	
970.	1975.	1980.	1985.	1990.	1995.
000.	3.0	4.0	5.0	7.0	9.0
1.0	15.0				

AFNC (TIME, A_{18},24) - Price of mined products

1	1	1	12	3	
970.	1972.	1974.	1976.	1978.	1980.
982.	1984.	1986.	1988.	1990.	1992.
.0	.9	1.0	1.1	1.2	1.25
.3	1.35	1.4	1.45	1.5	1.5

AFNC (TIME,A_{25},25)-Oil imports available (AIMP)

1	1	1	4	2	
970.	1980.	1990.	2000.	50000000.	50000000.
5000000.	20000000.				

AFNC (TIME, A_{31},26)-National unemployment (UEN)

1	1	1	4	2	
970.	1975.	1980.	1985.	.05	.08
07	.07				

AFNC (TIME, A_{32},27)-National wage rate (WRN)

1	1	1	4	2	
970.	1975.	1980.	1990.	6500.	6700.
800.	7000.				

AFNC (TIME, A_{36},28) - Reforestation rate (REFOR)

1	1	1	3	2	
970.	1980.	1990.	0.0	0.0	0.0

AFNC (TIME, A_{37},29) - Preservation rate (PRESER)

1	1	1	3	2	
970.	1980.	1990.	0.0	0.0	0.0

AFNC (TIME, A_{40},32) - Limit on tons of coal mined

1	1	1	6	2	
970.	1975.	1980.	1985.	1990.	1995.
5000000.	35000000.	100000000.	150000000.	200000000.	200000000.

AFNC (TIME, A,33) - Employee/output ratios for non-energy mining Sector (28)

1	1	0	3	2	
972.	1980.	1985.	.000025	.000018	.000016

AFNC (TIME, A,34) - Employee/output ratios for coal mining Sector (27)

1	1	0	3	2	
972.	1980.	1985.	.000011	.000009	.000007

AFNC (TIME, A,35) - Employee/output ratios for petroleum and natural gas Sector (26)

1	1	0	3	2	
972.	1980.	1985.	.000014	.000013	.000012

AFNC (TIME, A,36) - Employee/output ratios for construction Sector (1)

1	1	0	3	2	
972.	1980.	1985.	.000033	.000024	.000020

AFNC (TIME, A,37) - Employee/output ratios for food processing Sectors (2,3,4,5)

1	1	0	3	2	
972.	1980.	1985.	.000016	.000013	.000011

AFNC (TIME, A,38) - Employee/output ratios for forestry Sector (25)

1	1	0	3	2	
972.	1980.	1985.	.000030	.000021	.000017

AFNC (TIME, A,39) - Employee/output ratios for petroleum refining Sector (30)

1	1	0	3	2	
972.	1980.	1985.	.000005	.000004	.000004

AFNC (TIME, A,40) - Employee/output ratios for primary metals Sector (29)

1	1	0	3	2	
972.	1980.	1985.	.000009	.000007	.000006

AFNC (TIME, A,41) - Employee/output ratios for other manufacturing Sectors (6,7,8,9,10)

1	1	0	3	2	
972.	1980.	1985.	.000028	.000023	.000021

AFNC (TIME, A,42) - Employee/output ratios for railroad transportation Sector (11)

1	1	0	3	2	
972.	1980.	1985.	.000037	.000022	.000017

AFNC (TIME, A,43) - Employee/output ratios for motor freight Sector (12)

1	1	0	3	2	
972.	1980.	1985.	.000038	.000033	.000014

AFNC (TIME, A,44) - Employee/output ratios for communications Sector (13)

1	1	0	3	2	
972.	1980.	1985.	.000032	.000021	.000017

AFNC (TIME, A,45) - Employee/output ratios for utilities Sector (14)

1	1	0	3	2	
972.	1980.	1985.	.000014	.000010	.000008

AFNC (TIME, A,46) - Employee/output ratios for wholesale and retail trade Sectors (15,16)

1	1	0	3	2	
972.	1980.	1985.	.000078	.000064	.000058

AFNC (TIME, A,47) - Employee/output ratios for finance, insurance, and real estate Sector (17)

1	1	0	3	2	
972.	1980.	1985.	.000017	.000014	.000013

AFNC (TIME, A,48) - Employee/output ratios for services Sectors (18,19,20,22)

1	1	0	3	2	
972.	1980.	1985.	.000118	.000100	.000092

AFNC (TIME, A,49) - Employee/output ratios for enterprizes Sectors (21,22)

1	1	0	3	2	
972.	1980.	1985.	0.0	0.0	0.0

AFNC (TIME, A,50) - Employee/output ratios for agriculture Sector (24)

1	1	0	3	2	
72.	1980.	1985.	.0000407	.0000305	.0000265

AFNC (TIME, A_{44},62) - Price for residential gas

1	1	0	9	2	
70.	1975.	1976.	1977.	1978.	1980.
85.	1990.	1995.	.000001	.0000014	.0000016
.00002	.0000025	.000003	.0000035	.000004	.0000045

AFNC (TIME, Z,63) - Cost escalation of insulation

1	1	0	6	2	
973.	1974.	1980.	1985.	1990.	1995.
677	1.0	1.0	1.0	1.0	1.0

AFNC (TIME, P_{106},64) - Baseline energy consumption for space heating

1	1	1	6	2	
970.	1975.	1980.	1985.	1990.	1995.
35840000	135840000	130000000	125000000	123000000	120000000

AFNC (TIME, P_{100},51) - Federal government spending

1	1	3	0	2	
972.	1980.	1985.	.0000114	.000091	.000084

AFNC (TIME, P_{101},52) - State government spending

1	1	0	3	2
972.	1980.	1985.		

AFNC (TIME, P_{45},53) - Labor/population ratios (WPR)

1	1	1	5	2	
972.	1975.	1980.	1985.	1990.	.4
48	.51	.515	.52		

AFNC (TDO, PCMO,54) - Increase in production costs as oil supply is depleted

0	1	1	5	2	
.0	10000000000.	20000000000.	30000000000.	40000000000.	1.0
.25	1.5	2.0	3.0	5.0	

AFNC (OPADJ, X,4) - Incremental production costs of oil supply is depleted

1	1	0	12	3	
.5	2.51	2.52	2.53	2.54	3.0
.0	5.0	6.5	8.0	10.0	15.0
.0	5.0	10.0	15.0	20.0	25.0

AFNC (TDG, PCMG,55) - Increase in production costs as gas supply is depleted

0	1	1	5	2	
.0	1000000000000.	2000000000000.	3000000000000.	4000000000000.	1.0
.25	1.5	2.5	4.0		

AFNC (GPADJ, X,8) - Incremental cost of producing gas

0	1	1	12	2	
000050	.000051	.000052	.000053	.000054	.000080
000140	.006200	.000300	.000450	.000600	.000900
.0	5.0	10.0	15.0	20.0	25.0
0.0	35.0	40.0	45.0	50.0	55.0

AFNC (X, Y,3) - Oil investment expense

0	0	1	26	3	
.0	3.0	5.0	7.0	9.0	11.0
3.0	15.0	17.0	19.0	21.0	23.0
5.0	27.0	29.0	31.0	33.0	35.0
7.0	39.0	41.0	43.0	45.0	47.0
9.0	51.0	.0080	.0324	.0570	.0862
0808	.0404	.0269	.0117	.0117	.0117
0110	.0110	.0110	.0110	.0110	.0110
0110	.0110	.0110	.0110	.0110	.0110
0110	.0110	.0110	.0110	.0110	.0110

AFNC (X, W,1) - Oil production

0	0	1	26	3	
.0	3.0	5.0	7.0	9.0	11.0
3.0	15.0	17.0	19.0	21.0	23.0
5.0	27.0	29.0	31.0	33.0	35.0
7.0	39.0	41.0	43.0	45.0	47.0
9.0	51.0	.00067	.00337	.00853	.01572
02246	.02583	.02807	.02876	.02919	.02876
02807	.02583	.02246	.01797	.01382	.0114
00898	.00786	.00651	.00517	.00449	.00337
00247	.00112	.00022	.0		

AFNC (X, Y,2) - Oil operating expense

0	0	1	26	3	
.0	3.0	5.0	7.0	9.0	11.0
3.0	15.0	17.0	19.0	21.0	23.0
5.0	27.0	29.0	31.0	33.0	35.0
7.0	39.0	41.0	43.0	45.0	47.0
9.0	51.0	.00168	.00843	.02133	.03930
05615	.06458	.07018	.07190	.07298	.07298
07018	.07103	.06738	.05990	.05115	.04671
04191	.03930	.03581	.03102	.03143	.02528
01976	.01008	.00220	.0		

AFNC (X, Y,5) - Gas production

0	0	1	26	3	
.0	3.0	5.0	7.0	9.0	11.0
3.0	15.0	17.0	19.0	21.0	23.0
5.0	27.0	29.0	31.0	33.0	35.0
7.0	39.0	41.0	43.0	45.0	47.0

AFNC (X, Y,5) - Gas production (cont'd)

9.0	51.0	.00067	.00337	.00853	.01572
02246	.02583	.02807	.02876	.02919	.02876
02807	.02583	.02246	.01797	.01382	.0114
00898	.00786	.00651	.00517	.00449	.00337
00247	.00112	.00022	.0		

AFNC (X, Y,7) - Gas investment

0	0	1	26	2	
.0	3.0	5.0	7.0	9.0	11.0
3.0	15.0	17.0	19.0	21.0	23.0
5.0	27.0	29.0	31.0	33.0	35.0
7.0	39.0	41.0	43.0	45.0	47.0
9.0	51.0	.00000080	.00000324	.0000057	.00000862
00000808	.00000404	.00000269	.00000117	.00000117	.00000117
00000110	.00000110	.00000110	.00000110	.00000110	.00000110
00000110	.00000110	.00000110	.00000110	.00000110	.00000110
00000110	.00000110	.00000110	.00000110		

AFNC (X, Y,6) - Gas operating expense

0	0	1	26	3	
.0	3.0	5.0	7.0	9.0	11.0
3.0	15.0	17.0	19.0	21.0	23.0
5.0	27.0	29.0	31.0	33.0	35.0
7.0	39.0	41.0	43.0	45.0	47.0
9.0	51.0	.0000000335	.0000001685	.000004265	.000000786
000001123	.000001369	.000001488	.000001524	.000001547	.000001524
000001684	.000001808	.000001797	.000001797	.000001797	.000001710
000001616	.000001572	.000001497	.000001448	.000001572	.000001348
000001112	.000000560	.000000121			

AFNC (TDO, DRO,9) - Drilling required/unit of oil discovered as supplies are depleted

0	0	1	11	2	
000000000.	2200000000.	2400000000.	2600000000.	2800000000.	3000000000.
200000000.	3400000000.	3600000000.	3800000000.	4000000000.	.04
04	.06	.08	.10	.12	.14
16	.18	100.			

AFNC (TDG, DRG,10) - Drilling required/unit of gas discovered as supplies are depleted

0	0	1	11	2	
4000000000.	1600000000000.	1800000000000.	2000000000000.	2200000000000.	2400000000000.
5,000000000.	2800000000000.	3000000000000.	3200000000000.	3400000000000.	.0000010
0000015	.000002	.000004	.000008	.000015	.00002
00003	.00010	.100			

AFNC (TM, CI, K3) - Coal mining cost, distribution function #14

0	0	7	2	0	
.0	1000000000.	2000000000.	4000000000.	8000000000.	12000000000.
0000000000	8.50	8.75	9.00	9.50	10.00
5.00	100.				

AFNC (A, F0, K2) - Coal mining capital, function #13

1	1	1	3	2	
5	1.0	1.5	0.0	.5	1.0

AFNC (TIM, ACM, K1) - Coal mining cost, function #12

0	0	0	7	2	
.0	1000000000.	2000000000.	4000000000.	8000000000.	12000000000.
0000000000.	1.50	2.00	3.50	4.00	4.50

AFNC (X, Y, K4) - Coal cost distribution, function #30

1	1	1	3	2	
.0	.5	1.0	.5	1.0	1.5

AFNC (TM, ACM, K1) - Mining cost, function #15

0	0	1	9	3	
.0	1000000000.	200000000.	3000000000.	4000000000.	5000000000.
000000000.	7000000000.	8000000000.	1.5	1.6	1.8
.0	.25	3.5	10.0	30.0	300.0

AFNC (TM, ACM, K2) - Mining cost distribution, function #16

1	1	1	3	2	
.0	.5	1.0	.5	1.0	1.5

AFNC (TM, CI, K3) - Capital cost, function #17

0	0	1	9	3	
0	1000000000.	2000000000.	3000000000.	4000000000.	5000000000.
000000000.	7000000000,	8000000000.	1.5	1.6	1.8
0	2.5	3.5	10.0	30.0	300.0

AFNC (X, Y, K4) - Mine cost distribution, function #31

1	1	1	3	2	
0	.5	1.0	.5	1.0	1.5

AFNC (PR, R1, 11) - Investment rate/profit rate

1	1	0	4	2	
0	1.0	10.0	50.0	0.0	1.0
1.0	50.0				

AFNC (PBBA, A,57) - Rate insulation upgraded versus payback period

0	1	1	20	2	
.0	1.0	2.0	3.0	4.0	5.0
.0	7.0	8.0	9.0	10.0	11.0
2.0	13.0	14.0	15.0	16.0	17.0
8.0	19.0	1.0	.3	.2	.1
05	.04	.035	.03	.0275	.025
0225	.02	.018	.016	.014	.012
01	.005				

AFNC (PBC, FC,58) - Fraction of new houses insulated versus payback period

0	1	1	20	2	
.0	1.0	2.0	3.0	4.0	5.0
.0	7.0	8.0	9.0	10.0	11.0
2.0	13.0	14.0	15.0	16.0	17.0
8.0	19.0	1.0	.9	.8	.7
6	.5	.4	.3	.25	.20
175	.150	.125	.1	.075	.05
025	.01	.01	.01		

AFNC (Price, A,59) - Fraction of energy consumption for home heating in class A house versus payback period

1	1	1	4	2	
0000015	.000003	.0000045	.000006	1.0	.85
.80	0.75				

AFNC (PRICE A,60) - Fraction of energy consumption for home heating in class B house versus payback period

1	1	1	4	2	
0000015	.000003	.0000045	.000006	1.0	.88
83	.79				

AFNC (Price, A, 61) - Fraction of energy consumption for home heating in calss C house versus payback period

1	1	1	4	2	
0000015	.000003	.0000045	.000006	1.0	.9
32	.85				

AFNC (TIME, PRE,65)-Price of gas for industrial sector

1	1	1	6	2	
975.	1976.	1977.	1980.	1985.	2000.
0000009	.0000011	.0000011	.0000013	.0000013	.0000015

AFNC (TIME, PRS,66) - Price of coal for industry

1	1	1	6	2	
975.	1980.	1985.	1990.	1995.	2000.
.00000037	.00000042	.00000056	.00000071	.00000060	.0000006

AFNC (SAV, RC,67) - Fraction of industries that will switch versus savings

1	1	0	12	2	
.0	.1	.2	.3	.4	.5
75	1.0	1.25	.15	2.0	3.0
.0	.01	.22	.05	.09	.15
2	.22	.25	.26	.28	.29

AFNC (X, Y,56) - Increased capital required as production rate increases

1	1	1	6	2	
00000000.	400000000.	600000000.	500000000.	1000000000.	1200000000.
.0	.9	.6	.4	.2	.2

SAMPLE OUTPUT

Results through 1973

```
516  0.25964E 09 0.25964E 09
518  0.14884E 10 0.30000E 08
522  0.0         0.0         0.30000E 07 0.40000E 07
     0.10000E 08 0.20000E 08 0.0         0.30000E 08 0.0         0.40000E 08
     0.0         0.50000E 08 0.0         0.90000E 08 0.0         0.10000E 09
     0.0         0.10000E 09 0.0         0.12500E 09 0.0         0.12500E 09
     0.0         0.12500E 09 0.0         0.12500E 09 0.0         0.12500E 09
     0.0         0.12500E 09 0.0         0.10000E 09 0.0         0.10000E 09
     0.0         0.10000E 09 0.0         0.95000E 08 0.0         0.90000E 08
     0.0         0.85000E 08 0.80000E 08 0.0         0.75000E 08 0.0
     0.70000E 08 0.0         0.65000E 08 0.0         0.60000E 08 0.0
     0.55000E 08 0.0
     0.71431E 11 0.90000E 11 0.0         0.10000E 12 0.0         0.13000E 12
     0.0         0.13000E 12 0.0         0.15000E 12 0.0         0.15000E 12
     0.0         0.15000E 12 0.0         0.15000E 12 0.0         0.13000E 12
     0.0         0.12000E 12 0.0         0.90000E 11 0.0         0.80000E 11
     0.0         0.70000E 11 0.0         0.60000E 11 0.0         0.50000E 11
     0.0         0.40000E 11 0.0         0.30000E 11 0.0         0.30000E 11
     0.0         0.25000E 11 0.0         0.25000E 11 0.20000E 11 0.0
     0.20000E 11 0.0         0.20000E 11 0.0         0.15000E 11 0.0
     0.15000E 11 0.0
     0.37959E 08 0.40961E 08 0.40961E 08 0.40356E 08 0.40356E 08 0.39696E 08
     0.39696E 08 0.38981E 08 0.38981E 08 0.38211E 08 0.38211E 08 0.37386E 08
     0.37386E 08 0.36506E 08 0.36506E 08 0.35571E 08 0.35571E 08 0.34581E 08
     0.34581E 08 0.33536E 08
     0.72291E 07 0.55381E 07 0.55881E 07 0.55716E 07 0.55716E 07 0.55551E 07
     0.55551E 07 0.55331E 07 0.55331E 07 0.55111E 07 0.55111E 07 0.54891E 07
     0.54891E 07 0.54616E 07 0.54616E 07 0.54341E 07 0.54341E 07 0.54011E 07
     0.54011E 07 0.53681E 07
     0.50559E 07
     0.45983E 07 0.31500E 07 0.30500E 07 0.29400E 07 0.28400E 07 0.27300E 07
     0.26300E 07 0.25200E 07 0.24200E 07 0.23100E 07 0.22100E 07 0.21000E 07
     0.19200E 07 0.18900E 07 0.17800E 07 0.16800E 07 0.15800E 07 0.14700E 07
     0.13600E 07 0.12500E 07
     0.17852E 09
     0.0         0.30000E 08 0.29000E 08 0.28000E 08 0.27000E 08 0.26000E 08
     0.0         0.24000E 08 0.23000E 08 0.22000E 08 0.21000E 08 0.20000E 08
     0.0         0.18000E 08 0.17000E 08 0.16000E 08 0.15000E 08 0.14000E 08
     0.0         0.12000E 08
     0.59000E 08
     0.55420E 10
528   5140.4      9607.8      3385.0
      5755.2
    -0.29691E-03 0.15144E-01 0.11552E-01-0.37294E-02 0.80830E-02-0.12254
     0.20376     0.32552E-01 0.38491E-02-0.47275E-02-0.13823E-01 0.23910E-01
    -0.35104E-01 0.20544E-01 0.11385E-01 0.16529E-02 0.40069E-01 0.47434E-02
     0.11643     0.13566E-02 0.23878    -0.16474     0.17200     0.0
     0.0         0.0         0.0         0.0         0.12418E-02 0.25751E-02
     0.0         0.0         0.0         0.0         0.0
     0.39788E 09 0.10761E 09 0.44508E 08 0.39851E 08 0.67542E 08 0.28079E 08
     0.70144E 08 0.14457E 08 0.42377E 08 0.25379E 09 0.17653E 09 0.13823E 09
     0.10421E 09 0.21738E 09 0.17497E 09 0.51385E 09 0.55436E 09 0.11956E 09
     0.96013E 08 0.18525E 09 0.22988E 08 0.24223E 08 0.45708E 08 0.93100E 09
     0.29900E 09 0.10800E 09 0.17000E 08 0.17700E 09 0.44955E 09 0.23360E 09
     0.0         0.0         0.0         0.0         0.0
533  0.15560E 09 0.62888E 08 0.10562E 09 0.32968E 06 0.21450E 07
      1432.0      1333.3      1333.3
```

```
A 6   0.62900E 06  1.1875       3340.0       0.25323E 09 0.93112E 09 0.13161E 09
A 9   0.15600E 09 0.15000E 10 0.53600E 07
A14    5.6300       0.27200E-03 0.35827E 08 0.49932E 11 0.45196E 08
A17    3.6000       0.50659E 07 0.45937E 07
A20   0.92500       0.17852E 09 0.0
A25   0.30000E 09 0.15829E 09 0.17224E 08 0.17852E 09 0.50000E 08
      0.93112E 09 0.30000E 09 0.15829E 09 0.17224E 08 0.17852E 09 0.44273E 09
      0.23600E 09 0.0         0.0         0.0
       10500.
      0.21473E 09 0.0         0.0         0.0         0.0         0.0
      0.0         0.31974E 06 0.0         0.13121E 08 0.58566E 07 0.31584E 07
      0.54901E 07 0.11705E 08 0.21103E 08 0.21056E 08 0.23044E 07 0.0
      0.0         0.0         0.0         0.0         0.0         0.0
      0.0
      0.34536E 09 0.91549E 08 0.36406E 08 0.72522E 07 0.53785E 08 0.75045E 07
      0.15385E 08 0.27483E 07 0.27200E 07 0.19580E 09 0.11568E 09 0.65596E 08
      0.50910E 08 0.96465E 08 0.95701E 08 0.45897E 09 0.31658E 09 0.87674E 08
      0.36676E 08 0.14023E 09 0.41418E 07 0.38986E 07 0.11269E 08 0.0
      0.0
      0.39741E 09 0.11403E 09 0.46542E 08 0.39254E 05 0.69708E 08 0.12393E 08
      0.50721E 08 0.16286E 08 0.43858E 08 0.24897E 09 0.16563E 09 0.15114E 09
      0.89044E 08 0.23488E 09 0.18285E 09 0.51724E 09 0.63978E 09 0.12182E 09
      0.13607E 09 0.18625E 09 0.39490E 08 0.51126E 07 0.72539E 08 0.93112E 09
      0.30000E 09 0.15829E 09 0.17224E 08 0.17852E 09 0.44273E 09 0.23600E 09
      0.0         0.0         0.0         0.0         0.0
A29   0.59016E 06 0.76516E-01  6289.3
      0.21580E 06
      0.10344E 11 0.74090E 11 0.75145E 14 0.21520E 14 0.0
      0.39741E 09 0.11403E 09 0.46542E 08 0.39254E 08 0.69708E 08 0.12393E 08
      0.50721E 08 0.16286E 08 0.43858E 08 0.24897E 09 0.16563E 09 0.15114E 09
      0.89044E 08 0.23488E 09 0.18285E 09 0.51724E 09 0.63978E 09 0.12182E 09
      0.13607E 09 0.18625E 09 0.39490E 08 0.51126E 07 0.72539E 08 0.93112E 09
      0.30000E 09 0.15829E 09 0.17224E 08 0.17852E 09 0.44273E 09 0.23600E 09
      0.0         0.0         0.0         0.0         0.0
A32   0.68000E-01  6620.0
A34   -1300.1      19594.
A39   0.0         0.0         0.28529E 06 0.58459E 10
      0.31000E 03
A43   0.10015E 10 0.65488E 09 0.53900E 10
```

APPENDIX D

Price Scenario Input

After the baseline case was established, variations were made in some assumptions. The model then computes the effects of these new assumptions on natural/synthetic gas demand in Montana. Changes in assumptions were implemented through changes in input to the model. This appendix lists the input changes used for the scenarios in this report. All input values not listed here are unchanged from those used to establish the baseline case.

Case 1. Firm industrial inter-fuel substitution (before 1981). Input:

ISPRC = 1

Case 2. Firm industrial inter-fuel substitution (before 1981) and extrapolated industrial inter-fuel substitution (after 1980). Input:

ISPRC = 1

ISPRM = 1

Case 3. Residential conservation. Input:

ISCON = 1

Case 4. Firm industrial inter-fuel substitution and extrapolated industrial inter-fuel substitution and residential conservation; with the residential gas price increasing to $2.00/MCF in the year 2000. Industrial gas increases in price to $1.50/MCF in the year 2000.

Input:

ISCON = 1

ISPRC = 1

ISPRM = 1

Function 62 (Price of residential gas) was modified as follows:

Function control - 1, 1, 0, 6, 2

Independent variable (year) - 1975, 1976, 1977, 1980, 1985, 2000

Dependent variable ($/million Btu) - 1.4E-6, 1.6E-6, 1.6E-6, 1.8E-6, 1.8E-6, 2.0E-6

Function 65 (Price of industrial gas) was modified as follows:

Function control - 1, 1, 1, 6, 2

Independent variable (year) - 1975, 1976, 1977, 1980, 1985, 2000

Dependent variable ($/million Btu) - .9E-6, 1.1E-6, 1.1E-6, 1.3E-6, 1.3E-6, 1.5E-6

Case 5. Firm industrial inter-fuel substitution and extrapolated industrial inter-fuel substitution and residential conservation; with the residential gas price increasing to $3/MCF in the year 2000. Industrial gas increases in price to $2.50/MCF in the year 2000.

Input:

ISCON = 1

ISPRC = 1

ISPRM = 1

Function 62 (Price of residential gas) was modified as follows:

Function control - 1, 1, 0, 6, 2

Independent variable - 1975, 1976, 1977, 1980, 1985,
(year) 2000

Dependent variable - 1.4E-6, 1.6E-6, 2.0E-6, 2.25E-6,
($/million Btu) 2.35E-6, 3.0E-6

Function 65 (Price of industrial gas) was modified as follows:

Function control - 1, 1, 1, 6, 2

Independent variable - 1975, 1976, 1977, 1980, 1985,
(year) 2000

Dependent variable - .9E-6, 1.1E-6, 1.5E-6, 1.75E-6,
($/million Btu) 1.85 E-6, 2.5E-6

Case 6. Firm industrial inter-fuel substitution and extrapolated industrial inter-fuel substitution and residential conservation; with the residential gas price increasing to $6.50/MCF in the year 2000. Industrial gas increases in price to $6.00/MCF in the year 2000.

Input:

ISCON = 1

ISPRC = 1

ISPRM = 1

Function 62 (Price of residential gas) was modified as follows:

Function control- 1, 1, 0, 6, 2

Independent variable - 1975, 1976, 1977, 1980, 1985,
(year) 2000

Dependent variable - 1.4E-6, 1.6E-6, 2.0E-6, 3.5E-6,
($/million Btu) 4.5E-6, 6.5E-6

Function 65 (Price of industrial gas) was modified as follows:

Function control - 1, 1, 1, 6, 2

Independent variable (year) - 1975, 1976, 1977, 1980, 1985, 2000

Dependent variable ($/million Btu) - .9E-6, 1.1E-6, 1.5E-6, 3.0E-6, 4.0E-6, 6.0E-6